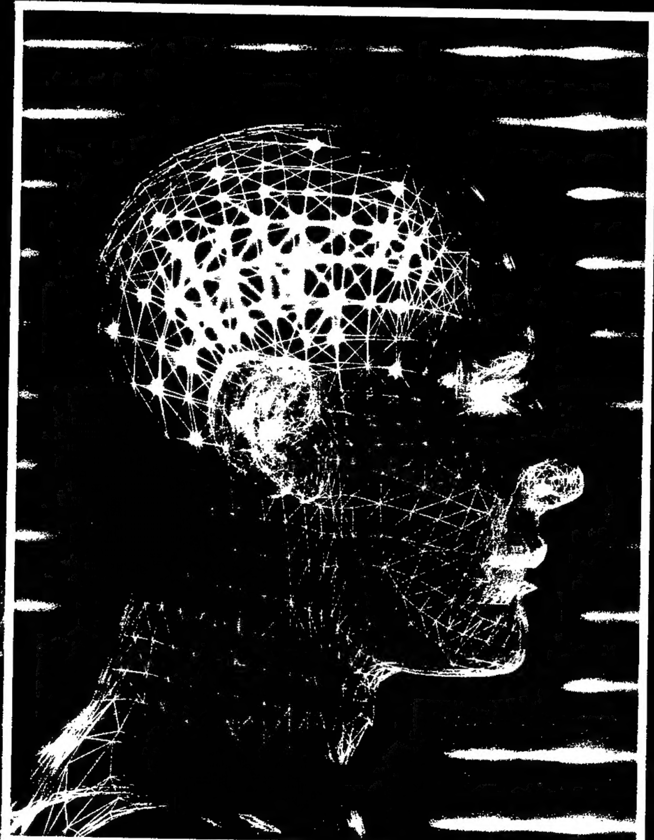

Understanding Commanders' Information Needs

James P. Kahan ◆ D. Robert Worley ◆ Cathleen Stasz

RAND | Arroyo Center

Reissued with a foreword by
General Gordon Sullivan (USA-Ret.)

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FOREWORD

I am honored to be asked to write a foreword to this important document. In this study is found an early appreciation of the complexities related to satisfying military commanders' information needs. This study is also, more significantly, a base document from which to measure progress as military leaders attempt to gain information dominance in our post–Cold War world.

Army leaders have always felt, subliminally if not specifically, that the "right information" would be available to them if only they could get it when and how they needed it. While this study shows this bias in an analog world of the mid-1980s, it importantly provides us with a logic for thinking through how information flows, or is drawn, to the commander in both the analog and digital worlds. Simply thinking "it's out there" is not good enough. Obviously, what was needed in the 1980s, as Army leaders wrestled with analysis to come up with a methodology, is more important today when it is possible to overwhelm the commander with mostly irrelevant data. Sensory overload is more apparent today than in the not-too-distant past.

Understanding Commanders' Information Needs is as important a study today as it was a decade ago. It will remain a seminal work for both theoreticians and practitioners of military art. Jim Kahan and his research team give practitioners the theory and the science; commanders, as always, create art from the science.

An important study that bridges the theory-practice gap.

Gordon R. Sullivan
General, USA, Retired

PREFACE

This report presents the principal findings of an Arroyo Center project entitled "Understanding Commanders' Information Needs," originally published in 1989. The project's sponsor was the Commander, Combined Arms Combat Development Activity (CACDA), Fort Leavenworth. The project took a social psychological view of the command-post information processing that serves the information needs of U.S. Army commanders at Echelons Above Brigade. Its results should be of interest to those concerned with Army training of commanders and general staffs as well as with the interface between the human and electronic parts of the command-and-control operating system.

Unless otherwise stated, whenever the masculine gender is used, both men and women are included.

The research for this project was carried out in the Arroyo Center, a federally funded research and development center sponsored by the United States Army.

SUMMARY

INTRODUCTION

A commonly held belief within the Army is that commanders of higher-echelon units (Echelons Above Brigade, or EAB) often fail to obtain the information that they need. The problem is viewed as a function not so much of unavailable information as of getting the right information in the right form to the right place at the right time, to be used in the right way.

In recent years, the Army has sponsored or conducted a variety of studies of varying methodological quality, all aimed at addressing the higher-echelon command-and-control problem.[1] These studies, most of which resulted in lists of commanders' information needs, have conceptual and methodological flaws that severely limit their usefulness. More important, we maintain that these studies have missed the main point of the problem. Commanders' information needs are rarely specific pieces of data but are instead highly variable and human-intensive elements. Therefore, any assessment of those needs must describe command-post information processing in a manner that captures the interactions between the commander and his staff in producing, transforming, and consuming information. Such a requirement implies, in turn, that information needs be examined from the dual perspective of information science and social psychology.

We view the command-and-control operating system as a hierarchically organized web of information sources—one that subsumes humans, computers, sensing devices, written documents, and the like. Accordingly, our approach looks at the largely human systems within the command post that integrate collective intuition, training, and experience with data. Only when these internal systems are understood can we begin to specify a design for the external systems that exchange information between the command post and the outside world.

[1]The appendix reviews five major attempts conducted or sponsored by the Army to enumerate commanders' information needs.

In the course of our study, we observed Army Group, corps, and division command posts in action over 12 different exercises. In addition, we interviewed a range of military experts, including doctrine writers and former commanders. Our interest in the commander led our observations and interviews to center on communications with him.

We focused on the content and the flow of command-and-control communications. Unlike earlier studies, we did not attempt to list the content of specific messages (i.e., *what*) or to chart the flow of such messages (i.e., *when* and *where*) through the command post; instead, we attempted to ascertain the reasons people communicated information (i.e., *why*) and to clarify the ends to which that information was to be applied (i.e., *so what).*

INFORMATION AND THE COMMANDER'S IMAGE

The commander seeks a dynamic *image* of the battlefield that will lead him to understand what *action* needs to be taken. This image, which is the commander's mental model of the battlefield and its contextual surroundings, includes military, political, and psychological considerations. Depending on the situation, the image probably has about five to nine major components, most of which are based on the traditional factors of METT-T (Mission, Enemy, Terrain, [own] Troops, and Time available). Further, the image is not merely a depiction; it also includes the commander's understanding of the history of the battlefield situation as well as his projected futures, which rest on his own and the enemy's possible actions. The *meaning* of any information gained by the commander is driven by the image that frames it, and the value of that information is determined by the manner in which it fits into the image. Therefore, staff members must share their commander's image if they are to understand and supply his information needs. Given this requirement, a major purpose of communications in the command-and-control process lies in the sharing of images.

Evidence supporting the primacy of image sharing comes from observations of commander-staff interactions in command-post exercises. Commanders typically seek options and assessments appropriate to their image rather than data. Even when commanders do request data, they usually do so for reasons related to images and image sharing, e.g., for staff training, for the validation of conclusions, or for ensuring that people are "reading off the same sheet of music." A commander typically makes his decisions before

the decision briefing takes place; hence, the main function of that meeting is to provide a common context in which those decisions can be understood.

How Do Images Work?

A number of organizational and cognitive catalysts promote the conversion of images into action. From an organizational perspective, the common experiences and knowledge of professional soldiers facilitate the building and sharing of images. The functional roles assigned to various staff streamline the image-sharing process in that knowledge is distributed among specialists, each of whom communicates his portion of the image.

The cognitive image shared at the command post has both military and psychological components. The military components bear on the strategic, operational, and tactical characteristics of the situation; the psychological elements include the perceived personal characteristics of both friendly and enemy commanders and staff.

Information Is Interactive

Information needs include not only the *content* of information but also its *flow*. The traditional view of command communications is that of a linear flow in which the subordinate supplies the commander with information and the commander in turn supplies the subordinate with decisions. A better model of information flow, and one that is closer to reality in well-functioning command posts, is interactive—one in which each passage of information is accompanied by feedback for the assessment of understanding. The intent, guidance, and orders of good commanders are followed by checks for evidence of understanding.

Interactive information flow occurs in a variety of ways. A traditional method is that of back-briefing, or repeating back to a commander the orders he has just given. Another example arises when a briefer is asked a detailed question to which the commander already knows the answer. Here, the commander seeks to verify that he and his staff share an image. The relatively unstructured continuous information exchange among staff sections also constitutes interactive information flow. A final example of interactive information flow can be found in the face-to-face contact that takes place between a unit commander and his subordinate commanders.

When Is the Wrong Content Conveyed?

Perhaps the primary cause of inappropriate information supply to a commander is misapprehension of the image. When the commander's intent is ambiguous, unspecified, incorrectly specified, or incorrectly interpreted, then the wrong information can be conveyed. Inappropriate content may also result from the difficulty of expressing uncertainty. Because there is no standard way to communicate uncertainty, common estimates of uncertainty in a given situation can be difficult to share. This can lead to different images of the battlefield and, consequently, to the generation of inappropriate information. A focus on the wrong level of detail may lead to inappropriate information as well; overly fine-grained information may yield the impression of overload while failing to convey sufficient content for a conceptualization of the larger picture. Finally, mismatches in time or in the location of information can lead to the communication of inappropriate content; information conveyed at the wrong time is often overtaken by events and therefore rendered irrelevant, while information communicated at the wrong place clogs up the system at some locations while leaving voids elsewhere.

IMAGE MAINTENANCE AND MODIFICATION

Our analysis of command-post communications resulted in the identification of three modes of information exchange between commander and staff. These modes, which we labeled the *pipeline*, the *alarm*, and the *tree*, differ in their demands on the command-and-control communication system.

The **pipeline** mode transmits information according to a set order and an established format. It is well suited to decisions whose input variables are known in advance but is inadequate if the need for information depends on the content of that information or, alternatively, if the decision's input variables are not known in advance.

The **alarm** mode signals the occurrence of one or more of a number of exceptional events. This mode is analogous to the "management by exception" style or to "interrupt-driven" computer systems. Alarms may be either explicitly set by commanders or implicitly set by subordinates' understanding of the commander's image. Either type of alarm is difficult to automate in an electronic information system because all possible contingencies cannot be identified in advance.

The **tree** mode is an inquiry-based, demand-pull means of searching for and acquiring information along the paths of a

hypothetical decision tree. In this mode, information is supplied in response to specific demands, which arise in turn from previously supplied information. The tree mode is necessary in context-dependent situations because the order in which the commander will want information is impossible to anticipate. Pure tree mode is hard to implement because the "bushiness" of even simple decision trees makes them difficult to specify and because commanders normally "look ahead" only a few nodes.

Comparison of Pipelines, Alarms, and Trees

Pipelines, alarms, and trees do not represent conflicting processes; rather, they are parts of a larger information system. When a commander does not have cause to question his image, he is in either a pipeline or an alarm mode (depending on whether he is actively or passively acquiring information). When the validity of the image or the staff's understanding of that image is in question, the commander turns to tree mode.

The information exchanged in the three different modes does, however, differ in its timeliness, level of detail, and degree of uncertainty. Pipelines trade off low timeliness and a set level of detail for a low degree of uncertainty. Alarms by definition require great timeliness and are often quite specific; the "fog of war" means that alarm information is highly uncertain. Trees carry information of greatly varying timeliness and detail; the nature of the commander-staff exchange will cause them to center on less uncertain information.

The three modes also differ in their demands on the underlying command-and-control system in terms of when to send information, what information to send, and how a large universe of data must be queried. Pipelines push scheduled information of a predetermined nature from a fixed universe. Alarms send information when it occurs, following explicit or implicit triggers from a large universe of possibilities. Trees supply information only upon explicit demand, drawing from a fairly large universe of information.

The three modes also differ in the nature of their interactivity. A pure pipeline is linear from bottom to top; information is pushed when it becomes available, to be assembled for delivery at a specified time and place. Alarms are linear from bottom to top as well, but they occur in response to triggers that are sent from top to bottom. Only trees are interactive in real time.

Information Content and Processing Mode

Figure S.1 portrays the intent and action elements of the command-and-control system as two cycles, with the three modes of information processing acting as links that transit from one cycle to another.

Mission planning is a cognitively intense activity that creatively integrates information from many sources; therefore, it relies heavily on the tree mode of information search and exchange. Mission effectiveness monitoring is a more standardized function that can be planned in advance and supported by the pipeline mode. If information is received that threatens the plan, an alarm will be triggered, transferring the command post to return to mission planning. A feasible plan is translated into a set of resource orders by an activity that, from a cognitive standpoint, is not unlike mission planning and also requires tree-mode processing. Resource-order monitoring is a standard procedure supported by the pipeline mode; again, alarms will signal a problem with resourcing that requires either new resource orders or new plans.

INFORMATION TRANSMISSION, DISTRIBUTION, AND STORAGE

We discuss the nature of "supply-push" and "demand-pull" information flow and of "fully partitioned" and "fully replicated" information storage systems in command-post environments. Our analysis of the modes of information exchange showed that pipeline and alarm modes necessitate a supply-push data flow orientation, while tree mode requires a demand-pull. This suggests that one cannot see the entire picture by looking only at the nature of information *flow*. It further implies that replacing supply-push with demand-pull might not constitute the correct solution.

As an alternative, we examined the Command-and-Control Information System (CCIS) from two perspectives: that of information *flow* and that of information *storage*. Treatment of the extreme cases of each dimension led us to a description of that dimension's properties. The relationship between those properties and the three information exchange modes then led to an understanding of tradeoffs sufficient to motivate a hybrid system that supports all three modes.

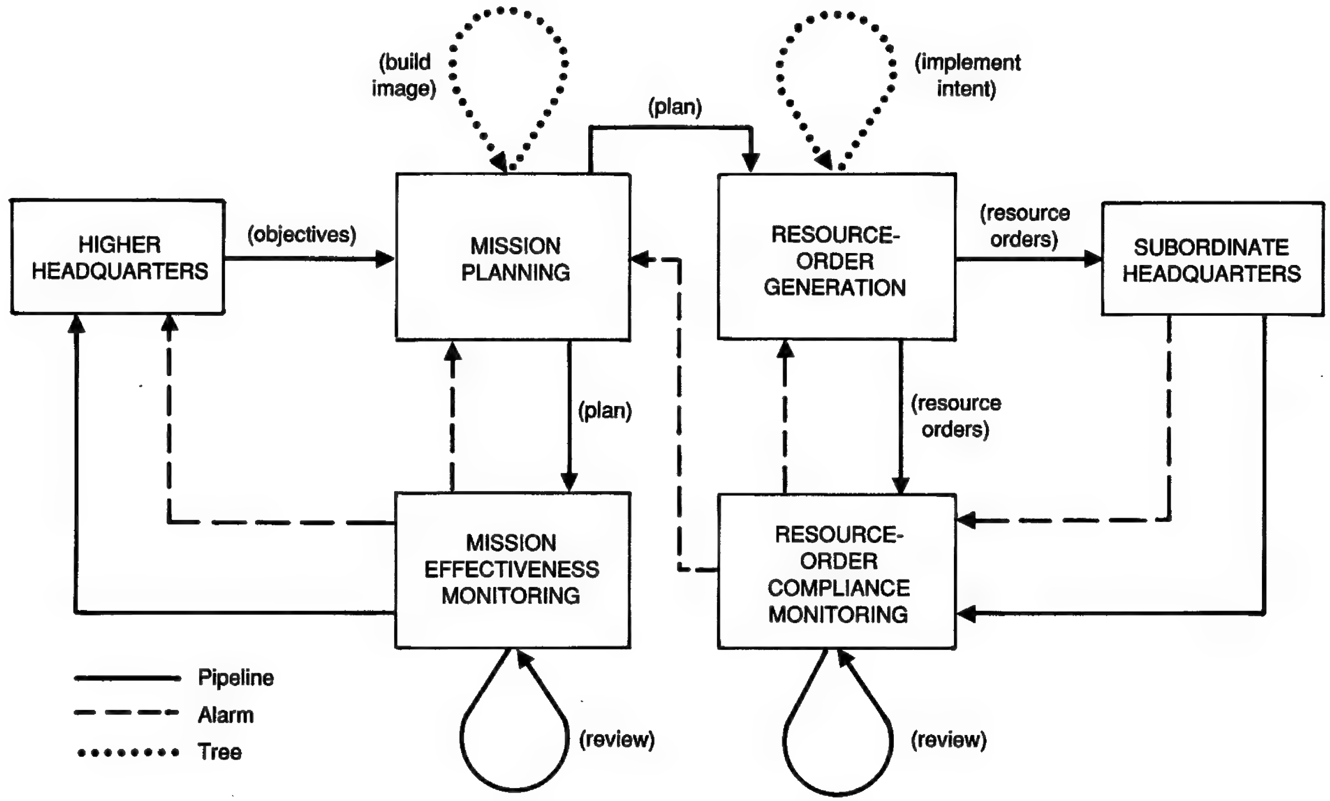

Fig. S.1—Information mode and command-post tasks

RECOMMENDATIONS: FULFILLING COMMANDERS' INFORMATION NEEDS

Our view of the EAB command-and-control system does not lead to specific information items or pathways to the fulfillment of commanders' information needs. Instead, we look one step deeper into the Army command-and-control problem to make recommendations for Army education and training and information systems design.

Education and Training

General staff officers must be educated in the art of constructing, understanding, and communicating images as well as in the formal procedures of performing defined staff activities. In the same manner, the training of EAB units must be oriented toward the sharing of images between the commander and his staff. We make several recommendations that should help achieve these objectives.

Institutionalize Back-Briefing. The sharing of an image requires feedback. We found this feedback to be present in well-functioning command posts but short-circuited in command posts that were under stress. We recommend that back-briefing be institutionalized to provide insurance that the commander is understood.

Teach Process as Well as Procedures. Effective command and control requires considerable expertise. Experts in most fields tend to make decisions by recognizing existing situations as analogues of their past experience, thus providing cues about what data to examine and what steps to take. The Army must provide educational opportunities to practice the processes used by experts as well as standard procedures.

Army education has been proceeding in the appropriate direction, as small-group discussions continue to replace mass lectures and as conceptual thinking supplants rote memorization. Further steps that can be taken to improve teaching expertise include teaching explicit ways of assessing understanding, stressing flexibility of information-processing behaviors, increasing the use of case studies, and having students practice not only their own tasks but also the decision tasks of their peers in other branches.

Train Unit Command Staffs to Share Images. A prominent gap between the potential and the reality of computer-driven command-post exercises (CPXs) lies in their inability to instill team

functioning, and hence the sharing of images, in the unit. What is needed are opportunities for the commander and staff to "read" each other and to practice turning intent into action across a wide range of circumstances. To fill this gap, we developed the concept of "sketchbook decision exercises," or small computer-supported CPXs that focus on specific thought problems over a wide range of situations.

Information System Design

Present information technology does not possess the sophistication to communicate directly in images. There are, however, steps that can be taken to remove impediments to image sharing that currently exist in the information system.

Identify Means of More Direct Image Sharing. The Army should seek out known means of passing images and should ensure that information systems, both human and automated, support these means. As an example, dynamic weather maps such as those used on local television news shows could be used to convey enemy or friendly intent.

Build a Hybrid Information System. The ideal information system is a hybrid of demand-pull and supply-push information flow and of fully partitioned and fully replicated information storage. Accordingly, the hybrid chosen should produce a system that supports pipeline, tree, and alarm modes of information exchange in equal measure. One can accomplish this by pushing information into a short-term, local storage facility from which necessary information can be filtered. The system should maintain a distributed information base such that rapidly needed information can be quickly met by access to local storage.

Establish an End-User to End-User Communications Orientation. Because of the strong emphasis on supporting supply-push, the pull is sometimes decoupled from the push. Current communications centers are active with respect to the communications network for which they feel responsible but are far more passive with respect to the recipients of incoming messages. We recommend that mechanisms be devised for distinguishing between scheduled information transfer and alarm annunciation so that recipients have a better idea of the immediacy of communications. We also advocate that information requests be coupled with responses to help requestors find the information they seek and to minimize redundant information flow.

ACKNOWLEDGMENTS

This report is based in large part on several visits to the NATO Central Army Group and the U.S. Army V, VII, and XVIII Airborne Corps in command-post exercises and to the 9th and 24th Infantry Divisions as they pioneered the Battle Command Training Program. In all of our visits, we enjoyed the full cooperation and gracious hospitality of these organizations. A great many individuals permitted us to observe them at work, discussed with us what they do, and helped us proceed to see others; we take this opportunity to thank them collectively for their efforts.

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We wish to offer special thanks to two individuals. Frank Camm of RAND has traveled with us, spent many hours discussing Army command and control with us, and thoughtfully and painstakingly reviewed multiple drafts of the paper. Lieutenant General Gordon

Sullivan, Deputy Chief of Staff for Operations and Plans, has encouraged us, opened doors for us, and, most important, allowed us to watch him think.

CONTENTS

FIGURES

TABLES

GLOSSARY OF ACRONYMS

AAR	After Action Review
ADC(M)	Assistant Division Commander (Maneuver)
ADC(S)	Assistant Division Commander (Support)
ARC	"The Art and Requirements of Command" Study
BCTP	(U.S. Army) Battle Command Training Program
CACDA	(U.S. Army) Combined Arms Combat Development Activity
CAS^3	(U.S. Army) Combined Arms Staff Support School, CGSC
CCIR	Commander's Critical Information Requirements
CCIS	Command-and-Control Information System
CENTAG	(NATO's) Central Army Group
CGSC	(U.S. Army) Command and General Staff College, Fort Leavenworth, Kansas
CGSOC	(U.S. Army) Command and General Staff Officer's Course, CGSC
CPX	Command-Post Exercise
EAB	Echelons Above Brigade
EEI	Essential Elements of Information
FLIRP	Force-Level Information Requirement Plan
FLOT	Forward Line of Own Troops
4ATAF	(NATO's) Fourth Allied Tactical Air Force
G1	Assistant Chief of Staff, Personnel
G2	Assistant Chief of Staff, Intelligence
G3	Assistant Chief of Staff, Operations
G4	Assistant Chief of Staff, Logistics
IPB	Intelligence Preparation of the Battlefield
IR	Information Requirement
MCS	Maneuver Control System
MEFT	Minimum Essential Functional Task
METT-T	Mission, Enemy, Terrain, (own) Troops, and Time available
NATO	North Atlantic Treaty Organization
NORTHAG	(NATO's) Northern Army Group
NTC	(U.S. Army) National Training Center, Fort Irwin, California
PIR	Priority Intelligence Requirement

SAMS	(U.S. Army) School of Advanced Military Studies, CGSC
SGI	Small-Group Instruction
SOP	Standard Operating Procedure
TOC	Tactical Operations Center
TRADOC	(U.S. Army) Training and Doctrine Command

I. INTRODUCTION

A PROBLEM IN HIGHER-ECHELON COMMAND AND CONTROL

In Napoléon's time, it was commonly held that a general could direct an operation "with his horse for transport, a spyglass for intelligence, a saddlebag for the command center, and a booming voice for communications."[1] At this time, the prescribed way to learn the art of war was to study the Great Captains and to gain experience through on-the-job training. Although there is still some merit in this approach, many years have passed since the Army has been capable of providing training by fire in a high-intensity conflict. Moreover, history cannot provide perfect lessons; as the modern battlefield has grown in space, time, and complexity, so too has the information needed by the commander increased in scope.[2] Correspondingly, the task of processing and reducing data to provide the commander with the essential information he needs has become increasingly complex. Thus, modern warfare places substantial information demands on the commander, his subordinate commanders, and his staff.

A common belief within the Army is that commanders of higher-echelon units (Echelons Above Brigade, or EAB) often do not acquire the information that they need for the decisions they must make. The problem is viewed as a function not so much of unavailable information as of getting the right information in the right form to the right place at the right time, to be used in the right way. Each of these elements—content, format, location, timing, and use—is *necessary* to good command and control.

Ample evidence exists that EAB command and control does not function smoothly. The Army Science Board[3] concluded that the Army command-and-control operating system is not exercised to practice or assess the way the system would function in wartime. Observers at almost all command-post exercises (CPXs) have noted problems in communication that have led to partial (or worse) failures in carrying out the commander's intent. New commanders complain

[1]Matthews (1987, p. 20).
[2]Van Creveld (1985).
[3]Army Science Board (1985).

that it takes at least an entire CPX to orient their staffs to their own information requirements, to the great detriment of unit performance. A recent book, *America's First Battles*,[4] documents the failure of EAB command and control in the first battle of each of America's major wars. In most of these initial battles, this failure of command and control led ultimately to defeat. Given the fast pace of modern high-intensity warfare, the Army may not always have the luxury of losing early battles while firming up its command and control.

PREVIOUS EFFORTS TO IDENTIFY COMMANDERS' INFORMATION NEEDS

In recent years, the U.S. Army has commissioned or performed several major studies that attempt to enumerate commanders' information needs.[5] With one exception, each of these studies had as its end product lists of commanders' critical information needs. Efforts to produce these lists have taken two approaches: task analysis and system design. In the task-analytic approach, analysts define the tasks that are required for the commander and his staff to execute their combat duties. Once these tasks have been identified, the analysts enumerate the data elements required for their performance. The systems approach attempts to specify the design requirements for an automated system that can facilitate the proper flow of information to the commander or staff officer. The two approaches are not mutually exclusive and are often combined in a single study.

Studies of commanders' information needs make a variety of assumptions in their problem statements, some seemingly valid and others less so. Underlying all of these assumptions, however, is the premise that the probability of making a correct tactical decision increases when key elements of information required by the commander are both available and accurate. Better information, then, is said to render tactical decisionmaking more accurate.

An assumption common to many studies is that the modern command post is overwhelmed by the volume of available information, rendering the staff unable to effectively filter out inessential information. Hence, it is held that critical information may be lost. Automation is seen to exacerbate this problem by producing a

[4]Heller and Stofft (1986).

[5]Bloom and Farber (1967); Herren and Moak (1986); Lockheed (1981); U.S. Army CACDA (1979, 1985a, and 1985b). We briefly critique these studies here; they are described in detail in the appendix.

kind of "information explosion." Technological advances in sensor systems, for example, are said to have developed to a point at which a commander can be inundated with incoming facts and statistics. Systems such as the Maneuver Control System (MCS) can produce over 100 automated reports to divisions and corps, some of which contain information that is critical for the force-level commander. The problem lies in identifying what subset of information is critical.

Another frequent assumption is that the information needs of a commander are finite, specifiable, and applicable across all scenarios that the commander may encounter. However, the level of detail for a specific element may vary, as might the information requirements of different echelons.

The studies we reviewed provided some insight into commanders' information needs but are flawed by a number of serious conceptual and methodological shortcomings that limit their utility for either understanding or designing information systems. In the remainder of this subsection, we discuss these shortcomings.

Conceptual Limitations

There Is a Lack of a Conceptual Framework. The principal drawback of the studies we reviewed lay in the absence of a conceptual framework of command and control from which to critically analyze commanders' information needs. Such a framework should capture, at a minimum, the decisionmaking and planning *processes* that drive a commander's information-seeking behavior and his information needs. Lacking this framework, the studies focus on pieces of the problem (e.g., information overload) or on the mechanics of that problem (e.g., how a piece of information gets to the commander), generally aiming only for technical solutions (e.g., automated or manual system specifications).

The Situational Framework Is Not Considered. Perhaps almost as serious as their lack of a conceptual framework is the studies' failure to recognize that the situational framework shapes a commander's information needs. Because their goal is reductionist—to reduce the number of information requirements to some manageable number—most of the studies strive to develop categories of information that are applicable across many situations. For example, one study did not specify what information was needed in the "current enemy situation" category. This was because the content and form of the information the commander needs to know about the enemy depend on his image of the current situation. Interviewees in

that study did not make judgments about data or processes in the context of an actual scenario but instead assigned a global rating across all of their experiences. Similarly, respondents in another study were given no specific scenario or key decision as a basis for the selection of commanders' critical information requirements.

Information Needs Are Not Assessed from the Commander's Perspective. In the studies we examined, information needs were viewed more as entities that somehow had to get to the commander rather than as items sought by the commander. An often-heard piece of Army wisdom is that data become information when they're used. We would argue that the perspective of the user is critical to the determination of information needs; having commanders or staff officers check off a list of plausibly needed information items does not constitute use in this sense.

It Is Assumed That Information Needs Can Be Ranked. Each of the studies we examined, in its attempt to reduce the quantity of information needed, made questionable assumptions about the prioritization of information. Two methods were used for such prioritization. In the first, a vote was taken among the respondents, and information nominated by more than a certain percentage of respondents was labeled "high priority." In the second, respondents were asked to judge which items were most critical. In our view, neither of these methods is satisfactory. The voting procedure implicitly assumes that all commanders are the same and that responses constitute random selections from a common prioritization, with important items more likely to be listed. This assumption is not valid in that different commanders have varying information needs; to deny the needs of the nonconformist commander may be to disable the creative thinker just when he is most needed. The ranking method is subject to the criticism of failing to consider the situational framework; different frameworks will result in very different rankings. Indeed, as we argue below, it is impossible to prioritize commanders' information needs *a priori and abstractly*.

Methodological Limitations

Results Were Not Corroborated. The most severe methodological limitation of the studies is that none examined the reliability or validity of the lists that they generated. In all cases, subjective judgments, which are by nature variable and error prone, serve as the source of data. The studies neglect to calculate the reliability of these

judgments or to estimate how often the same responses would result if the questions were to be asked a second time. There is some indication that reliability may have been low; in those studies that did employ second panels of judges, the second panels did not always agree with the first ones.

Nor were the results validated. In no case was the criticality of information tested in an actual, or even a simulated, decisionmaking context. On the few occasions when efforts were made at cross-validation, the results did not bode well for validity. Furthermore, in some cases, the resulting lists had questionable face validity. In one study, for example, omission of weather data led to the dismissal of the study by a division commander respondent.

There Was No Consensus Among the Studies. The studies we reviewed varied widely in the number of "essential" elements of information they identified, which ranged from 20 to 62,900. Many of the studies qualified their results by stating that the number arrived at was either too small, because it did not account for special circumstances, or too large in that it could not effectively inform the design of decision aids. The studies also varied in the number of information categories (e.g., intelligence, operations) that were seen as essential as well as in the level of aggregation of the data. In one study, for example, 14 of the 38 corps commander's information needs were in personnel/logistics; in another, all of those items were subsumed under the single (and highly ranked) piece of information termed "assets available (operable by type)." Given that commanders will differ in the level of aggregation that they need, it is impossible to identify any single level of aggregation as *the* appropriate one. These inconsistencies further suggest that the establishment of a definitive list is an elusive, if not impossible, task.

A DIFFERENT ORIENTATION

With one exception, the studies we reviewed began with reasonable assumptions but took a faulty approach; they ignored the observation that "effective command is largely a process whereby men, machines, and materiel are manipulated by a skilled and experienced individual to achieve prescribed goals."[6] That is to say, they tended to focus on *tasks* rather than *process* or on *available* rather than *needed* information or data. Further, the concentration on technology for handling the overload problem shaped the studies in ways that seem

[6]Bloom and Farber (1967), p. 7.

to have impeded progress toward understanding information needs. In effect, these studies attempted to reduce the encyclopedia of all possible information available to the commander down to a slim volume of essentials. We believe that such an objective is unrealistic, especially at EAB; the nature of war is too complex and the interaction of relevant variables too complicated to provide a formula for a set of information that would be adequate over all conditions. As Napoléon commented when discussing the "higher spheres" of war,

> Everything depends on the character that nature has given to the general, on his qualities, on his faults, on the nature of the troops, on the range of weapons, on the season, and on a thousand circumstances which are never the same.[7]

Moreover, the addition of automation and electronic battlefields does not alter the basic nature of the problem. Van Creveld[8] states:

> Taken as a whole, present-day military forces, for all the imposing array of electronic gadgetry at their disposal, give no evidence whatsoever of being one whit more capable of dealing with the information needed for the command process than were their predecessors a century or even a millennium ago.

A Commander's-Eye View of Information Needs

Presented here is a summary of our observations of the manner in which EAB commanders obtain their information.

A commander's information needs are rarely specific pieces of data that can be transmitted directly from outside the headquarters; instead, they are information items whose development requires the explicit participation of headquarters staff and subordinate commanders. Examples of information items that we observed are as follows:

- Estimates of enemy intentions, predicated on a belief about the enemy's overall strategic objectives supported by intelligence information.
- Evidence that headquarters staff understand the commander's intent and can use that intent to prepare alternative courses of action and plans.

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[7]Napoléon (1870, p. 365; translated by Luvaas, 1986, p. 2).
[8]Van Creveld (1985, p. 265).

- Alternative courses of action and plans, with prospects and risks for each.
- Evidence that subordinate commanders understand and are prepared to implement the commander's concept of operations.

All of these elements appear to be necessary for the commander to maintain a coherent *image* of his battle.[9] When the information is consistent with that image, then much of the information supplied to the commander can be in a standardized form; the commander will "spot check" that standard information with detailed follow-up questions to test the validity of the image. However, information indicating to the commander that his image is in need of revision generates requests for specific items that are highly dependent on the perceived anomaly. Some examples may illustrate this point:

- It is important to the commander that his subordinate commanders understand his concept of operations. If there is information indicating that one of the subordinates does not understand the concept of operations (e.g., the subordinate has taken an unexpected action), then the commander will in all likelihood visit that subordinate commander either to reconcile the violation of expectations or to revise someone's understanding.
- If the commander receives an intelligence report that is inconsistent with his image of the enemy's intent, he will ask for specific detailed information with which to refine his understanding, will assess the validity of the intelligence report, and will obtain revised estimates of enemy intent consistent with the intelligence report.
- The commander constantly receives updates about the capabilities of his own forces, especially before they change objectives or postures, and often visits subordinate command posts to verify the accuracy of the information.
- During all of his information gathering, the commander is constantly looking for weakness in both the enemy and his own situation. When these are found, he attempts to exploit the former and correct the latter. The commander also assesses the risks associated with such exploitations and

[9]In the next section, we shall develop the concept of the commander's image in greater detail.

corrections. He expects his subordinate commanders and his staff to engage in such information searches and analyses and to inform him immediately if they find anything noteworthy.

- If the commander receives information to the effect that there is an imminent enemy breakthrough at a particular point and that the breakthrough can seriously affect his overall concept of operations, then he will ask for more detail than he typically receives about that point, for information about units that could affect the battle near that point, and for knowledge of the air and reserve assets available to commit to that point. He might also visit his subordinate commanders one or even two echelons down.

The Situational Framework

We conclude from our observations that information systems must be designed to provide a commander with what he needs rather than to disgorge for him what is already there. Previous information systems have attempted to provide all of the information that a commander might need and to push that information into the command post and thence onto the commander. These systems have the potential to overwhelm the commander with mostly irrelevant data while wasting valuable command-post staff resources. To eliminate these risks, the system must respond to specific information requests that query the universe of possible data and extract the critical information items. Acknowledgment of the need for such a "demand-pull" system leads in turn to a focus on interactive information processes that will provide information in a flexible yet rapid way.

Listed below are some of the elements of the situational framework that drive commanders' information needs. The first two items on the list are fairly standard and well recognized. The last two are less well known *in terms of defining information needs*; hence they define the focus of this report.

- *The context of the command decision.* The particular situation in which the commander finds himself (METT-T,[10] stage of the war, political considerations, etc.).

[10]METT-T is the standard Army acronym for the five essential characteristics that define a battle situation: **M**ission (from higher headquarters), **E**nemy (location, strength, and disposition), **T**errain (and weather), **T**roops (friendly available, location, strength, and disposition), and **T**ime horizon.

- *The organizational structure of the command post.* The organization of the command post, including the specialists present, their fungibility, and the communication among staff members, determines which staff members receive specific information and how they process that information. This in turn determines what information is available to the commander.
- *The commander's image.* The commander's image, or mental representation of the situation, drives his information needs. His identification of the nature of the problem—e.g., its critical aspects, the center of gravity of the battle, and the culminating point—provide the framework for his information gathering. Different commanders have different images and therefore different information needs. But these differences do not necessarily predict how good the commander is or gauge the quality of his decisions.
- *The interaction between the commander and his immediate subordinates.* Just as the nature of the individual commander is important, so are his perceptions of and interactions with his subordinates. If a commander believes that his subordinates understand him and are competent, then he will require far less information than he would if this were not the case. Correspondingly, a subordinate who understands the commander can communicate information more efficiently than can a subordinate who does not.

We believe that the problem of understanding higher-echelon commanders' information needs must be examined from perspectives that did not exist in the time of Napoléon: those of social psychology and information science. The interpersonal aspect of information exchange is critical to the commander; he seeks information that has a great deal of human input, both from his subordinate commanders (in their evaluations of their own situations) and from his headquarters staff (in their assessments, estimations, plans, and courses of action). As an earlier investigation into the art and requirements of command put it,

> Command is primarily a "people process" rather than a formal system; successful commanders are effective because they are people- rather than systems-oriented . . . . General officers continue to express the belief that personal visits and personal reconnaissance cannot be supplanted by technological devices; *both* technology and

> personal contact are essential to the successful exercise of command.[11]

The implication of our orientation is that we must look at the largely human systems within the command post that integrate collective intuition, training, and experience with data. The recent literature on knowledge transfer[12] stresses that human filtering of information is important for ensuring the relevance and quality of that information. Only when these internal systems are understood can we anticipate the effects of different potential designs for external systems that collect and transmit data between the internal systems and the outside world.

A central corollary of our assumptions is that one of the most important pieces of information for a commander is whether or not his subordinates understand his image of the battlefield. If the commander is assured that his subordinates do understand his image, then his own information seeking can be more passive. If, on the other hand, the commander's subordinates do not understand his image, the commander's information seeking must be intensive, as he must attempt to communicate his image while also involving himself in all phases of the command-and-control process to ensure that his intent is carried out. The information that tells the commander which of these two information-seeking styles he should adopt is ultimately one of the most critical determinants of his behavior.

STUDY METHOD

Our main approach to the study of information at EAB was to observe command posts in action over several exercises. From 1986 through 1988, we observed 12 different CPXs. Units observed include the NATO Central Army Group (CENTAG), three U.S. Army corps (in both Europe and the United States), and three U.S. Army divisions. At these exercises, we attended commanders' decision briefings, intelligence and operations section meetings, and joint planning meetings as well as observing "the action" at the Tactical Operations Center (TOC), planning cells, and other locations. When their schedules permitted, we talked with command-post staff ranging from the commanding generals to enlisted clerk-typists about their tasks and their views of information at the command post. We also

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[11] Bloom and Farber (1967, p. ix).

[12] See, for example, Bikson, Quint, and Johnson (1984).

attended the After Action Reviews (AARs) and "hotwashes" of each of the exercises we observed. Following our observations, we occasionally returned to the unit that we had observed to present and discuss our preliminary findings.

In addition, we interviewed experts on higher-echelon command and control, including doctrine writers and former commanders and general staff members. These interviews took place at RAND's Washington office, the U.S. Army Command and General Staff College (Fort Leavenworth, Kansas), the U.S. Army War College (Carlisle, Pennsylvania), the U.S. Air Force War College (Montgomery, Alabama), the U.S. Naval Postgraduate School (Monterey, California), and the National Defense University (Washington, D.C.).

Given our focus on commanders' information, our observations and interviews centered on direct and indirect communications with the commander. In Fig. 1.1, an abstract schematic of a command post, the solid lines show the communications on which we concentrated. The dashed lines indicate other communication channels that, while important to command and control, did not have a direct bearing on our project.

OUTLINE OF THE REPORT

We focused on the content (in terms of the commander's image) and the flow (between commander and staff and among primary staff members) of command-and-control communications. Unlike earlier studies, we did not attempt to list the content (i.e., *what*) or to chart the flow (i.e., *when* and *where*) of specific messages through the command post. Instead, we observed communications in an attempt to determine the purpose and importance (i.e., *why*) of generated information and to define its ultimate use (i.e., *so what*). Section II of this report details our observations.

Our observations led us to characterize command-post information processing in terms of three different modes of communication that are employed at the command post: pipeline, alarm, and tree. Each of these three modes portrays a different communication relationship between the commander and his staff, and each places different demands on the command-and-control operating system. Section III of this report defines these modes and describes their effects on the content and flow of information to the commander.

A Command-and-Control Information System (CCIS) that can adequately service pipelines, alarms, and trees cannot be either a

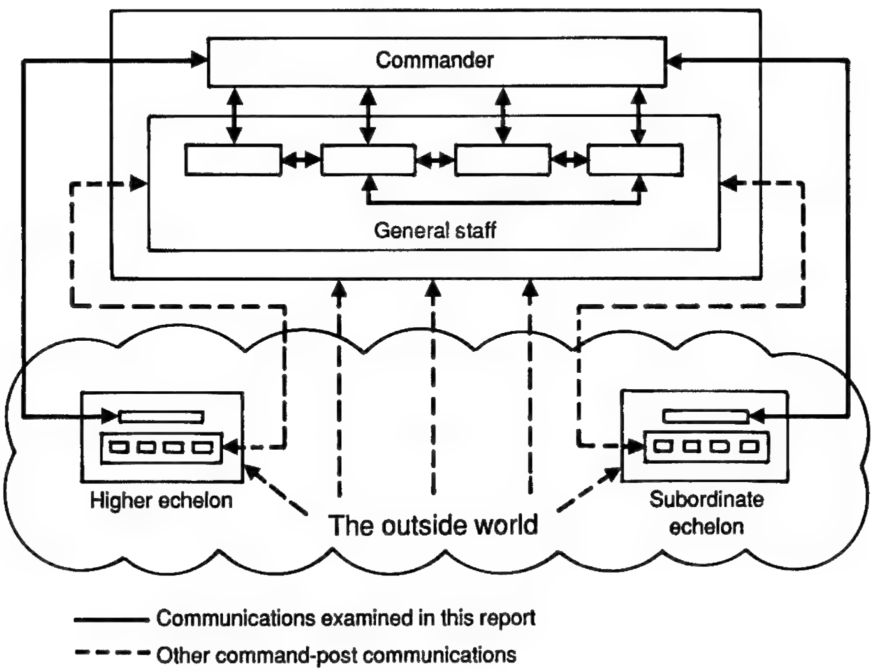

Fig. 1.1—Information at the command post

pure "supply-push" or a pure "demand-pull" system. To construct a hybrid system, we must consider the information storage characteristics of the CCIS as well as its information flow. In Sec. IV, we develop these concepts in detail.

We transformed our "social psychological" analyses of the command-and-control operating system from the abstract to the more concrete by considering their implications for commander and staff education and training[13] and for information systems design. For these two areas, our analysis yielded recommendations either in the form of changes in Army procedures or in the form of proposals for further research to specify changes that should be made. In Sec. V, we present and discuss these recommendations.

[13]Somewhat arbitrarily, we use the term *education* to refer to activities largely taking place within schoolhouses and aimed at individual officers. Correspondingly, by *training* we mean activities involving intact units and aimed at improving unit performance.

II. INFORMATION AND THE COMMANDER'S IMAGE

PLANNING AN OPERATION

A very important meeting for most commanders is the planning meeting, at which the commander and his primary planning staff (typically the Chief of Staff, G2, G3, and planners) set into motion the command-post work that will result in the commander's ultimate guidance and orders. We shall set the stage for this and the following section by narrating a planning meeting that might have taken place.[1]

In this fairly typical CPX, the commander has received guidance from higher headquarters to defeat the enemy first operational echelon in detail and to maintain the Forward Line of Own Troops (FLOT) east of Phase Line Boise. He has received reinforcements from the theater reserve to help him accomplish his mission. In the commander's mind, the main decisions he must make are (1) how to posture the units under his command; (2) what to do with his reserve; and (3) how to allocate his deep-air resources. In terms of METT-T, he knows the mission, the terrain, the time frame, and the gross characteristics of where both enemy and friendly troops are located. What he would like to know is the enemy intent and the readiness of his troops for different postures.

The meeting opens with the commander asking his G2 for an assessment of the enemy main effort. The commander believes that this effort will be in the south instead of the north, but the G2 maintains that the evidence is equivocal and refuses, even after considerable probing, to commit himself. After this interchange, the commander concludes, "OK, if I can't shake you from your position, I'll go along with you, even though my own gut feelings tell me that there isn't room enough up north to mount a main attack."

The commander then asks the planning officer to relate what the planning cell has done about possible enemy main efforts in both the

[1]This semifictional meeting is an amalgam of several planning sessions we have observed at several CENTAG, corps, and division exercises. Although the specifics are invented to keep the discussion at an unclassified level, the interactions reflect our actual observations.

north and the south. The planner tells his story by projecting future scenarios rather than by providing numerical details. From time to time, the commander interrupts to ask for a detail.

Following the planner's tale and some discussion, the commander moves to clarify a misunderstanding. His earlier guidance had been to create plans to "block the enemy." By "block the enemy," he now explains, he did not mean to form a wall. Instead, he constructs a metaphor with football defensive linebacker play: he means to "blitz"[2] the stronger enemy force first and then to counterattack against the weaker force. In the interim, the weaker force may have made a minor penetration; if so, the defending forces should withdraw in a manner that shapes that penetration to make it vulnerable to a counterattack. In conducting this operation, the commander explains to his staff, he risks (1) misidentifying the stronger enemy force; (2) not being able to successfully stop the advance of the stronger force; and (3) not being able to limit the penetration of the weaker force to the extent and shape permissible. Because of the G2's unwillingness to commit himself to an enemy intention, the commander is unwilling at this time to gamble that the stronger force is in the south.

The remainder of the planning meeting revolves around what intelligence must be gathered to identify the stronger of the two enemy forces (i.e., the main attack), how to position the reserve so that it can move either north or south as needed, how to posture friendly forces given either enemy contingency, and how to allocate deep-air resources. The discussion is a lively one, involving the participation of all of the attendees.

The complexity of the plan is fully discussed. The commander notes that the roles of his subordinate units are complicated and subject to misinterpretation. He states that "if this were not an exercise, I would be at [a particular subordinate] headquarters at first light to talk directly with [its commander]."

The meeting concluded, the planners work through three courses of action, each of which, in their minds, will fulfill the commander's intent for this operation. The next morning, they privately brief the commander; one hour later, at the decision briefing, the commander publicly chooses one of the courses of action, and the associated orders are issued.

[2]That is to say, he intends to concentrate his defensive forces in an offensive posture in order to seize the initiative, disrupt enemy timing, and drive the enemy offensive backward.

A MODEL OF IMAGES AND ACTION

Keegan[3] labels the essential elements of command action *knowing* and *seeing*. By "knowing," Keegan means having a general background knowledge that provides a rich context, largely in terms of METT-T. By "seeing," Keegan refers to having a dynamic image of the battlefield that leads the commander to understand what needs to be done. The information content the commander requires thus arises from his image of the situation. We describe here a framework by which that content can be identified.

Figure 2.1 depicts the framework within which the commander seeks information. The commander seeks to build an *image* of the situation that can be translated into *action* by the forces under his command. The image begins with the commander's current view of the situation plus his mission from higher headquarters.[4] The commander's own training and experience,[5] plus his understanding of the appropriate doctrine,[6] together shape his *intent*.

What Is an Image?

At any arbitrary starting point in time, the commander has an internal model, or image, of what "reality" is. In terms used by academics who study thinking and learning,[7] an image can be defined as the commander's mental representation or model of the situation that faces him. Depending on the situation and on the individual commander, the image has about five to nine major factors, most of which are based on METT-T. This is because doctrine and training have led Army commanders to conceptualize battlefields in METT-T terms.

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[3]Keegan (1987), pp. 325–326.

[4]The mission is the commander's interpretation of the guidance that he has received from higher headquarters. The mission may differ from what the higher commander intended in his guidance for any of a number of reasons, including failure of the guidance to reach the commander, having the guidance overtaken by events, or misinterpretation of the guidance.

[5]Commanders, like experts in most fields (Schon, 1983), tend to solve problems and make decisions by recognizing existing situations as instances of things with which they are familiar— i.e., on the basis of their past experience.

[6]Doctrine here includes Army doctrine, joint and combined doctrine where appropriate, and restraints and constraints imposed on the commander by political or strategic factors.

[7]See, e.g., Brown and Burton (1986), Gentner and Stevens (1983), Norman (1983), and Orr (1986).

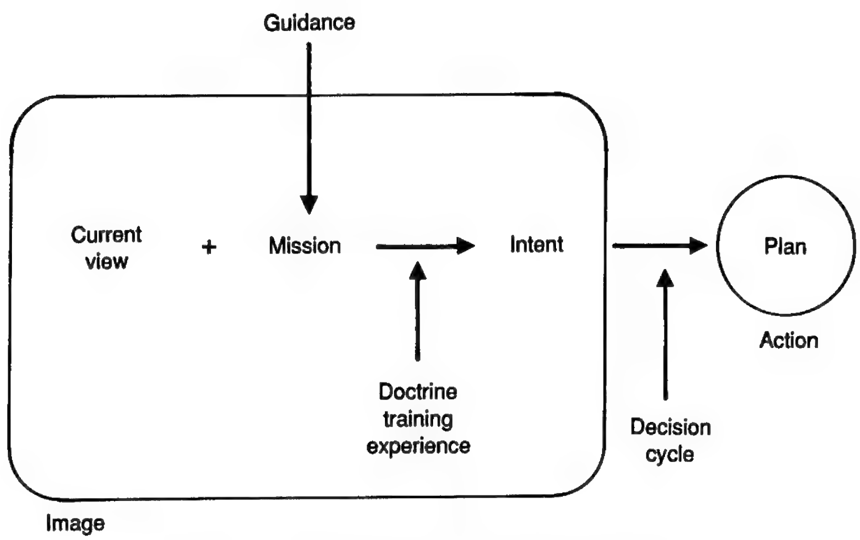

Fig. 2.1—Translating an image into action

The commander's image is on a level of detail sufficient for the decisions that he must make. Detail below that level is desirable only if it does not interfere with things that must be known. Detail that is insufficient to the task of decisionmaking will cause the commander to actively seek information.

This view of the commander's image and his need for information coincides fairly closely with that of van Creveld:

> From Plato to NATO, the history of command in war consists essentially of an endless quest for certainty—certainty about the state and intentions of the enemy's forces; certainty about the manifold factors that together constitute the environment in which the war is fought, from the weather and terrain to radioactivity and the presence of chemical warfare agents; and, last but definitely not least, certainty about the state, intentions, and activities of one's own forces.[8]

[8]Van Creveld (1985, p. 264).

The command-post decision cycle is the vehicle by which the image is converted to action. Since the image, which is a mental representation, cannot be directly inspected, the commander must do what he can to communicate it. This may be done verbally, metaphorically, or by means of some concrete pictorial or physical analogy. The command staff interacts with the commander, exchanging information where needed, until they understand the commander's intent well enough to produce a plan. This plan, when accepted and translated into an approved course of action, results in a published concept of operations.[9]

In our planning example, the commander formulated an image of the situation that called for quick action against the stronger enemy thrust and for a holding action against the weaker thrust, all within a mission to block an enemy attack. During the planning meeting, the commander needed two important pieces of information: where the enemy main attack was coming from and whether or not his planners understood his image. The first piece of information was not available; he therefore adopted a contingent strategy and tasked his intelligence staff to obtain critical data. The second piece of information indicated that his image was not well understood; he therefore took great pains to communicate that image and to verify that his staff understood it. Once it became evident that the staff understood the image, discussion turned to how to construct courses of action that would convert the image into a concept of operations that subordinate echelons could act upon. Staff members, armed with their understanding of the commander's intent and the necessary details of information, were then able to provide satisfactory courses of action.

Sharing Images

In our view, the main purpose of communications in the command-and-control process is to share images.[10] Images, however, are far from precise; research indicates that images or "mental models" may take many forms and may differ substantially in their detail, even

[9]Present Army doctrine calls for the commander's concept of operations (i.e., what he wants done) to be issued along with his intent (i.e., why he wants it done). Some within the Army find the publication of the intent extraneous and would eliminate it; our own view is that the intent, to the extent that it enables subordinate echelons to understand the commander's image, is important and should continue to be issued.

[10]As one commander we observed expressed it, his purpose in conducting exercises was to have his unit "achieve a common understanding of the commander's intent and warfighting philosophy."

within the same domain.[11] Yet a person's view of the world and of the tasks he is asked to perform rests heavily on the models he brings to the situation;[12] models that have a good correspondence to physical reality generally support learning, understanding, and performance, while inappropriate or inadequate models can lead to misconceptions and errors.[13] It is important, then, that the commander's and staff's images or models, although idiosyncratic, have a great deal of overlap and that their "shared" image be as congruent with reality as possible. This shared image must remain central even as it is continually refined and verified.

Although information is *understood* in the context of shared images, images are *conveyed* through messages. The *formal* vocabulary of the command post is limited largely to matters concerning METT-T. The commander asks for courses of action and particular items of information, gives guidance or orders, and states his intent. Staff members respond with estimates, plans, options, or particular data (e.g., weather or terrain).

When the formal vocabulary of the command post is inadequate, prudent commanders and staff will attempt to convey their images more directly. In our example, the commander used the linebacker analogy, strained as it was, because formal guidance was inadequate to the task of conveying his image. On another occasion, after the planning staff had spent an inordinate amount of time trying to identify the doctrinal "second tactical echelon of the enemy first front echelon" to attack with deep-air assets, the G3 entered the room and cut the Gordian knot by going to the map, pointing at an enemy unit, and saying, "I mean these folks!"

Implications of Thinking in Images

Because the image underlies any communication at the command post, the meaning, much less the importance, of any information is driven by the manner in which it is perceived within the context of the image. No information can be understood in isolation from that context. Before his planning meeting, for example, the commander had employed the metaphor of "blocking the enemy." But the term "blocking" can convey many images; it can mean creating a wall to prevent passage, placing impediments to slow the rate of movement,

[11]See, for example, Carroll and Thomas (1982).
[12]Gentner and Stevens (1983); Linde (1988).
[13]Norman (1983, 1986).

or, as it meant here, counterattacking. In the planning meeting, the commander amplified his blocking metaphor by adding the story of the linebacker. This enhanced metaphor helped the staff share the commander's image. Consequently, the staff was better able to provide information, in the form of courses of action, that was both appropriate and useful.

Because no information can be understood apart from its contextual frame, the *value* of any particular piece of information cannot be determined out of context. Therefore, it is impossible to construct any abstract measure or prioritization of a commander's information needs. While it might be possible to construct a general ordering of information or even several "canonical" images, each with an information priority, there is no guarantee that an actual wartime situation will fit the most likely canons, and the risk is great that constructing information systems to deliver the highest-expected-value information first will also have a great likelihood of not delivering information in the needed priority. The real-world resolution to this problem, which we address in more detail in Sec. III, is that in times of need, information priorities are established in an interaction between commander and staff.

Data vs. Information

A major implication of communication in images—and one that is borne out by our observations—is that commanders need options and assessments that are relevant to the shared image instead of data in the form of prearranged lists of facts. Rather than seeking a detailed weather report, for example, the commander wants to know whether his planes can fly or if the winds will preclude a chemical attack. Hence, a commander looks to his G2 for his *assessment* of the enemy's intentions, not just for a litany of intelligence estimates of enemy position. As one commander we observed put it when asking his G2 what the enemy was going to do, "OK, John, it's time to earn your pay." In our planning-meeting example, the staff framed its discussions in terms of options and assessments. At another time, a staff member briefed data at length, concluding after five minutes, "In summary, sir, [Unit X] is in trouble." The commander immediately replied, "Why didn't you tell me that in the first place?" and proceeded to instruct his staff that his real needs were for assessments, with data needed only in exceptional cases. He completed his lecture with a plea to "treat me like a human being, not a computer."

The commander cited above clearly demonstrated, in both word and deed, that when a commander requests "data," the reason for his request may not be obvious. To be sure, there are situations in which the commander legitimately needs data for straightforward reasons. In our planning-meeting scenario, for example, the commander needed to know the enemy axis of advance. But the commander may request data for less obvious reasons—e.g., for staff training or for validating his subordinate's conclusions. Alternatively, a commander may simply seek to ensure that people are "reading off the same sheet of music" and that they continue to do so in the future. For example, the extended dialogue between the commander and the G2 in the planning meeting was intended partly to provide data for the commander's own thinking, partly to validate the G2's conclusion that the enemy axis of advance could not be reliably assessed, and, in all likelihood, partly to teach all of the participants at the meeting what to look for in preparing an assessment.

The typical decision briefing, which at a superficial glance can be thought of as a commander's primary source of information, is in a sense more *theater* than provision of information. The commander rarely obtains new information during that briefing; typically, he has already obtained the information he needs and has made his decision in earlier, private meetings. In the theater of the decision briefing, each actor, while nominally briefing the commander, is playing to the entire audience so that all of the participants may share a common context in which to understand the commander's decision. Only when this common context is understood can the individual staff sections accurately execute their parts of the decision.[14]

During exercises, commanders with a proclivity toward teaching employ briefings to "instruct" the staff regarding what they view as important or how to interpret data. This instruction facilitates image sharing while guiding the implementation of plans. After a weather report, for example, a commander asked the briefer to repeat which way and how strong the wind would blow that day. He then turned to the G2 and asked if the wind would preclude enemy use of chemical agents. In all likelihood, the commander knew the consequences of

[14]To be sure, the task of ensuring execution of the commander's plan is at least as important as the task of preparing that plan. As General George S. Patton, Jr. (1947, p. 308), observed, "In carrying out a mission, the promulgation of the order represents not over ten percent of your responsibility. The remaining ninety percent consists in assuring, by means of personal supervision on the ground, by yourself and your staff, proper and vigorous execution." In this sense, then, the decision briefing is aimed more at getting the decision carried out than at deciding.

the wind conditions but wanted to let the assembled staff hear an example of how information should be used.

A commander may also ask questions to validate a subordinate's conclusions. In the planning meeting, this was the essence of the dialogue between the commander and the G2. Because the G2's conclusion violated the commander's expectations, the commander asked for more information to check the G2's thinking. The details of enemy status that were discussed were less important to the commander than how the G2 had used those details in preparing his assessment.

HOW DO IMAGES WORK?

Given the idiosyncrasy of images and the difficulty inherent in communicating them, how is understanding achieved? We observed a number of organizational and cognitive catalysts that promote the sharing of images and the conversion of plans into action.

Organizational Catalysts Promote Image Building

From an organizational perspective, the Army provides commanders and their staffs with common experiences and knowledge from which to build and understand images of battle. Perhaps the most important part of this base is a common doctrine that defines warfighting terminology and procedures while providing a "standard" for appropriate commander and staff behavior.

The translation of doctrine into behavior is achieved by systematic training throughout the career of the professional officer as well as by education at branch schools, the Combined Arms Staff Support School (CAS^3), and the Command and General Staff College (CGSC). This education attempts to provide a common base of both conceptual knowledge and operating procedures. Our own observations of training exercises lead us to concur with the Army Science Board conclusion[15] that Army education in this regard is generally good. Thus, during the CPXs we observed, staffers in the vast majority of cases satisfactorily fulfilled the doctrinal procedures that their jobs called for.

"War stories," ubiquitous in the Army, essentially serve as metaphors for conveying important lessons and are often invoked to make a point in decisionmaking or planning sessions. The Army has

[15]Army Science Board (1985).

a well-developed sense of the importance of history, and these stories, if used appropriately,[16] provide a focus for common thinking. Van Creveld lucidly describes the importance of organization:

> The nature of the task is not the only determinant of the amount of information required for [command]; equally important is the structure of the organization itself....Confronted with a task, and having less information available than is needed to perform that task, an organization may react in either of two ways. One is to increase its information-processing capacity; the other is to design the organization, and indeed the task itself, in such a way as to enable it to operate on the basis of less information. These approaches are exhaustive; no others are conceivable.[17]

The communications structure of the command post is an important determinant of effective supply of a commander's information needs. In the course of our observations of CPXs, we noted three principles that appeared to be prerequisite to effective command-post functioning:

1. The command post should be organized to consolidate majorfunctions and to shorten communications paths. These cells do not necessarily correspond to the traditional general staff section (personnel, intelligence, operations, logistics) structure. For EAB, the major functions appear to correspond to rear, close, and deep operations.
2. There needs to be a single information sink to which people can refer if they need basic situation information in a hurry. The TOC provides this function for most command posts.
3. The chain of command, like the commander's telescope, must be capable of extension or contraction as needed. Where sharing of images is important, vertical distance is reduced as much as possible. Thus, commanders may need to spend considerable time with G3 shop assistants if those assistants are doing the main tasks of planning.

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[16]See Neustadt and May (1986) for an excellent description of the appropriate use of historical thinking and Marvin (1988) for an application of that thinking to military history. Additionally, Orr (1986) shows the usefulness of such stories for acquiring expertise in technical tasks.

[17]Van Creveld (1985, pp. 268–269).

On those few occasions during each exercise where we observed problems in command-post functioning, those problems were found to be attributable to the violation of one or more of these three principles. In one exercise, for example, the TOC was run by an officer who, having failed to understand the importance of that center's information function, did not have critical information when it was needed. At another exercise, the commander's guidance was issued several hours late because the junior officer in charge of writing that guidance had been unable to attend the decision briefing at which it was orally issued (all the seats had been occupied by officers of higher rank). As a result, the junior officer obtained the guidance third hand, and his first draft was rejected by the commander. For a final example in this vein, notification of the commencement of hostilities in one exercise was communicated from higher-headquarters intelligence to the intelligence section and for some reason wasn't formally sent to operations for four hours.

The structuring of command and control around a decision cycle also helps create a shared image. The commander and his staff build their separate images and bring them together at a number of meetings. As we discussed earlier, the main purpose of the command decision briefing is to maintain a common image of the situation. In our example of the planning meeting, the discussion between the G2 and the commander about the location of the enemy main attack was an example of this process at work. The commander had an incomplete image of the situation, asked for clarification, but accepted that his image couldn't be further refined at that time. Simultaneously, the staff learned both the nature and the uncertainty of the commander's image.

The functional roles assigned to various staff streamline the image-sharing process because everyone doesn't have to know everything. Knowledge is distributed among specialists, each of whom communicates his portion of the image. This distributed knowledge base is not only efficient but necessary, since a single individual simply cannot grasp all of the detailed complexities of modern warfare. The commander's role is that of the generalist; he must leave the details to his staff.

The Psychological Side of Image Building

The very nature of human communication is one that promotes image building. Humans have a variety of resources with which to detect and remedy (and at times exploit) the inevitable uncertainties

that arise in communication. Understanding is usually implicit, absent evidence of failure to understand. When such evidence occurs, the parties discuss the misunderstanding until a belief in shared understanding is achieved.[18]

The cognitive image shared at the command post has both military and psychological components. The military ones include shared knowledge of the general political, strategic, and METT-T characteristics of the situation. This shared knowledge gives the commander and his staff a base from which to build and understand an image of the battle. General Sir Martin Farndale, recently retired commander of the NATO Central Front Northern Army Group (NORTHAG), noted in an interview that he had spent 30 of his 42 years of service outside the United Kingdom, much of it in the NORTHAG sector. As a consequence, he had personally walked a substantial proportion of his command sector and felt comfortable in his knowledge in detail of the terrain restrictions on enemy capabilities.

The psychological components of the image are also important. Commanders make assessments about the personal characteristics of their subordinates and the enemy, and these assessments can strongly influence their intent. For example, if it is known that a subordinate commander will persevere against all odds, then an appeal from that subordinate will be given more credence than will a similar message from others. By contrast, a subordinate commander believed to be "weak" will not be trusted with critical positions; even in exercises, we saw one commander reject certain options because he believed a subordinate to be incapable of carrying his load. If a commander knows that one of his subordinate commanders is a risk taker, this assessment can influence his estimate of whether or not a particular course of action will be successful. If a commander trusts a staff member, information from that individual will be taken at face value; briefings from less trusted staff members will be more closely scrutinized and checked for validity.

A commander is also eager to have information about his enemy counterpart. Knowledge of the personal character or habits of the enemy commander can help him formulate an understanding of the enemy's intentions and interpret other intelligence information. In one exercise, for example, the commander was told the identity of the enemy commander opposing him. He then informed his staff that this particular enemy commander was known to devote an inordinate

[18]See, e.g., Suchman (1987).

amount of training time to night exercises and that, as a consequence, they could anticipate night action.[19]

INFORMATION FLOW IS INTERACTIVE

We turn now to a consideration of the information *flow* between commanders and their subordinates. The traditional view of command communications is one in which the subordinate supplies the commander with information and the commander in turn supplies the subordinate with decisions. Doctrinal publications such as the *Staff Officer's Field Manual* (FM 101-5)[20] provide details and examples of how to present information about METT-T, options, and assessments to a commander. Figure 2.2, which appears many places in the Army,[21] shows the manner in which information flows back and forth from commander and staff in linear fashion from mission received to mission accomplished.

While linear flow is a widely accepted model of information flow, a model that is closer to reality in well-functioning command posts is one in which flow is not linear but interactive: each passage of information in Fig. 2.2 is part of a feedback loop, and each step in the command-and-control process is accompanied by checks on understanding (see Fig. 2.3). As we discussed in the previous section, commanders engage in dialogue with staff members to ensure that everyone understands the content and the importance of the information provided. When the commander issues his intent, guidance, or orders, this is accompanied by feedback from the staff to the commander providing information that the intent, guidance, or orders have been understood.

[19]In another exercise, when the commander requested information about the opposing enemy commander, the control team, caught unprepared, replied that such information was irrelevant. This led to bad feeling between the command-post staff and the control team and quite possibly had negative consequences for the exercise beyond the loss of that particular piece of information.

[20]U.S. Army (1972). Note that this field manual is currently being revised by the CAS^3 faculty; this revision is more consistent with our viewpoint than the 1972 document.

[21]See, e.g., U.S. Army (1972, Fig. 5.5) and Shirron (1984). It is also prominently displayed at the Battle Command Training Program and at other higher-echelon training efforts.

Interactive Information Flow Is Necessary

Interactive information flow is necessary because both *information* and *needs for information* are communicated by this means.[22] The content of a briefing for a commander must be guided by what the commander needs; therefore, the briefer must know not only the content of his message but also the needs of his audience. Similarly, it is as important for the commander to know that his image of the battlefield is understood as it is for him to have that image. When a commander and a subordinate are "of one mind," the commander's job is greatly simplified; he can exercise command and control with greater confidence and spend less time monitoring the subordinate's execution of orders. Therefore, the commander looks for evidence that his subordinates understand him.

The very nature of the commander-subordinate relationship dictates a need for interactive information flow. Because he has neither the specialized skills nor the time to perform all the duties of command and control, the commander delegates authority to his subordinates while keeping unto himself the responsibility for the results of their actions. This means that, in the issuance of authority, the commander is asking the subordinate to "do what I would do if I had the time and specialized skills to do your job." But in order to maintain his responsibility, the commander must be confident that the subordinate is, in fact, acting in accordance with the commander's own image. Therefore, there is a second part of authorization that asks, "Prove to me that you understand me." Both questions—the delegation and the confirmation of understanding—must be resolved if the commander's will is to be executed.[23]

Interactive information flow is also necessary because command-and-control actions are incremental. A mission is accomplished by successive steps. Many of these steps, such as the preparation of courses of action, are themselves accomplished by successive iterations. Each iteration in turn requires its own feedback loop, as indicated in Fig. 2.3.

[22]We acknowledge an intellectual debt to Bateson (1972), to Laing, Phillipson, and Lee (1966), and to Watzlawick, Weakland, and Fisch (1974) for this line of thinking. See Kahan (1980) for an elaboration of the concept of the communication of understanding.

[23]The delicacy of this situation cannot be overstated. On the one hand, a good commander wants to give trusted subordinates free rein to exercise their own creativity. But on the other hand, the exercise of that creativity must be within the framework of the overall image. The history of warfare is replete with tragic stories of subordinates brilliantly doing the wrong thing.

How Interactive Information Flow Takes Place

Interactive information flow occurs in a variety of obvious and not-so-obvious human interactions; here, we shall describe a sampling of this variety.

A typical method of interactive information flow is the back-briefing. In it, a staff member briefs back to the commander his own version of what the commander just told him. In this way, the commander can immediately ascertain the staff member's understanding.[24]

Another obvious but perhaps more subtle example of interactive information flow is the "validity check" that takes place during briefings. The validity check occurs when the commander interrupts a briefing to ask a detailed question to which he already knows the answer. The ostensible reason for the question may be that the commander wants to obtain a piece of information. As we discussed earlier, however, the real reason for the question may be less obvious. The commander may, for example, seek to verify that he and the briefer are sharing an image. Alternatively, he may be aware that both he and the briefer know the answer but is seeking to ensure that the remainder of the audience gets the point. In this light, the validity check serves as an example of interactive information flow.

Other examples of interactive information flow derive from interaction among staff members. Although a staff is functionally partitioned so that individuals can focus their specialized skills, it cannot operate without a dialogue. For example, the G3 cannot plan without knowledge of enemy capability and intent, supply status, or fire support capability; this knowledge is supplied by fellow staff officers, not by subordinates within the "G3 shop." This information exchange is far less structured than that which takes place between staff and commander during a decision briefing. Rather than employ a structured, scheduled briefing, the staff constantly interact. They monitor, analyze, and plan, occasionally pushing extraordinary information at a fellow staff officer and demanding information from peers that they need in order to perform their tasks.

[24]Although back-briefing exists as a recognized procedure in the Army, it has no formal status and is too often one of the first things to go when time pressure becomes great. We observed one exercise in which the commander dispensed with the back-briefing because "the guys understand what I want anyway." The ensuing 24 hours proved to the unit's chagrin that "the guys" had seriously misunderstood what the commander wanted.

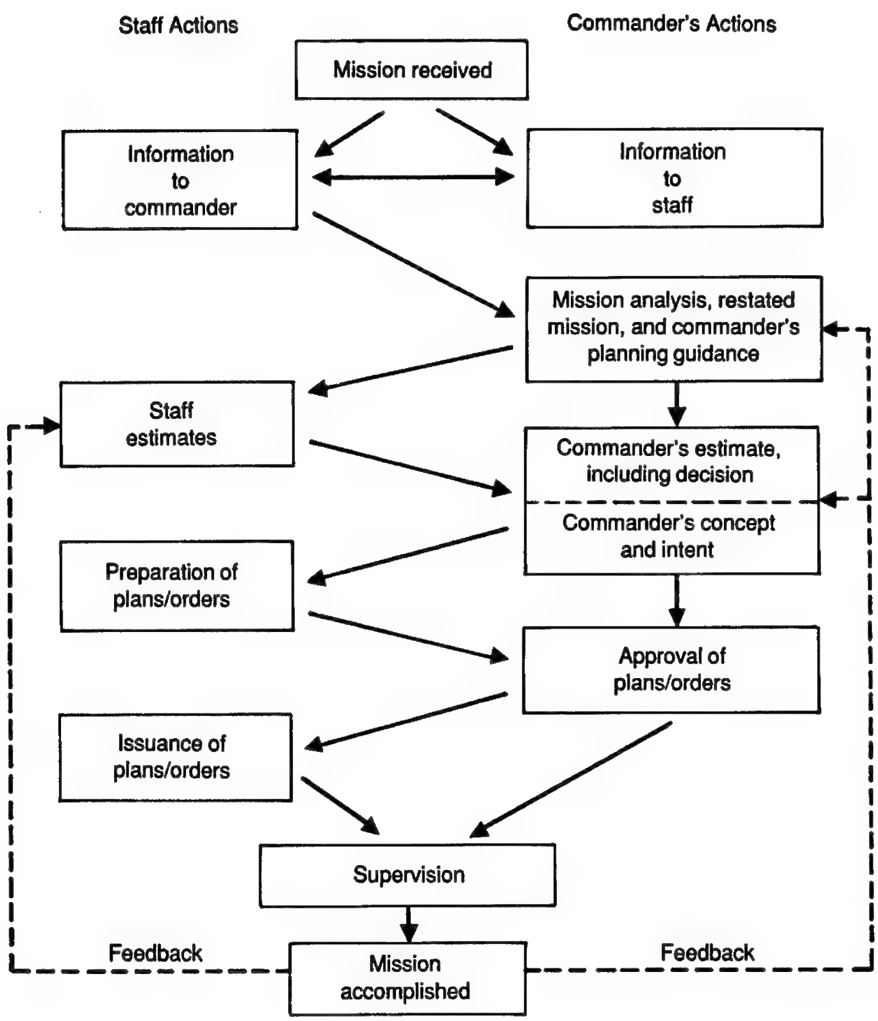

Fig. 2.2—Linear flow of commander/staff information (adapted from FM 101-5)

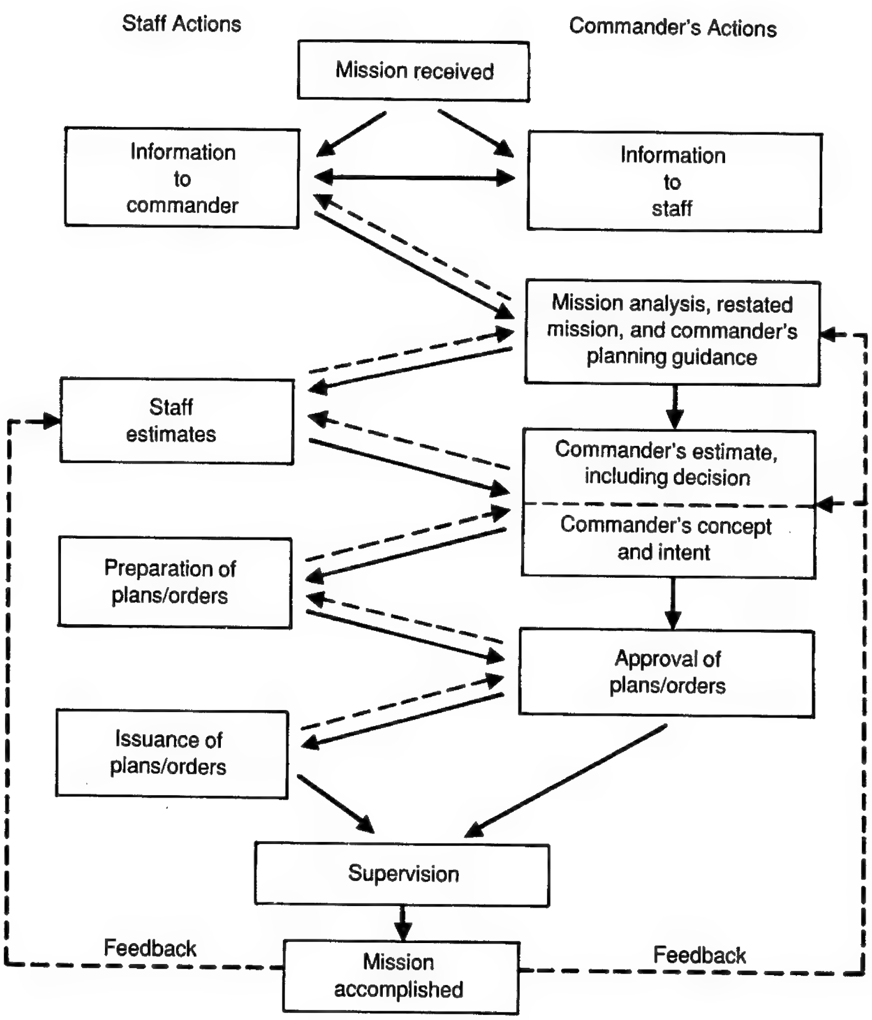

Fig. 2.3—Interactive flow of commander/staff information (adapted from FM 101-5)

A final example of interactive information flow can be found in the face-to-face contact that takes place between a commander and his subordinate commanders. In our interviews, both active and retired commanders stressed the importance of face-to-face contact with subordinate commanders as a means of ensuring that they shared a common image. During exercises, the single lament we most heard from commanders was that the restrictions of exercise play and the outside world rendered them unable to visit subordinate commanders. One of the "war stories" we heard was about General Omar Bradley, who would regularly visit the main command posts of his subordinate commanders. If General Bradley found the subordinate there, he would fire him, because the subordinates were supposed to be visiting their own subordinate commanders.

WHEN IS THE WRONG CONTENT CONVEYED?

A discussion of how the image drives information content must also consider the ways in which the wrong information can be conveyed. In our observations of exercises, we noted a number of instances in which inappropriate (as opposed to erroneous) communications occurred. The inappropriateness could have been due to an error either of commission or of omission.

Misunderstanding the Image

Perhaps the primary cause of inappropriate communication has its origins in a misunderstanding of the image. When a commander's intent is ambiguous or unspecified or when a staff member incorrectly interprets a commander's intent, then the information that they send is directed at a false image. In one exercise we observed, a commander had an ambiguous image of the way in which his subordinate units were to coordinate with one another; consequently, there was a logjam as the maneuver elements of one unit attempted to move along a road at the same time as the logistic elements of another. In this instance, the commander assumed the blame for having been too vague (even though he had not been personally responsible for the lack of cross-unit communication). In another exercise, the G3 misinterpreted the commander's intent and instructed his planners to prepare an inappropriate course of action. The planners, who had heard the commander directly and had correctly understood his intent, attempted to correct the G3 but were unsuccessful. Later, when the planners presented the course of ac-

tion, the misunderstanding was cleared up, but at the expense of substantial work and loss of time.[25]

Expressing Uncertainty

A second cause of inappropriate content is the difficulty of expressing uncertainty.[26] As van Creveld[27] states, the entire command-and-control process may be viewed as a (largely frustrated) search for certainty. General Sir Farndale notes:

> No war has ever started exactly as predicted in peacetime, so we must expect to be surprised in some aspect of the initial attack, either by timing, concept, tactics, weapons, or a combination of these. We must therefore . . . be ready for the unexpected.[28]

Substantial pressure exists for staff members to know the answers to questions; waffling and doubt are not considered characteristics of the good Army officer. Also, simple and straightforward answers are far preferred to convoluted, qualified statements. As a consequence, staff members are likely to present uncertain information without elucidating the extent of their uncertainty.[29] Hence the commander may not fully realize what is known and what is not known about the situation and may thus construct a faulty image or ask for inappropriate information.

Our interviews with intelligence staff (for whom this problem is particularly important) revealed that there is no standard way to communicate uncertainty or to convey the relative likelihood of different estimates of enemy intention. The better intelligence officers present alternative estimates only if, in their judgment, the different situations might warrant different decisions on the part of the commander.

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[25]In this instance, the planners, in spite of specific instructions to the contrary from the G3, also prepared courses of action in accordance with their (correct) interpretation of the commander's intent, so the situation was "saved."

[26]This problem is by no means restricted to the military. See, e.g., Arkes and Hammond (1986) or Kahneman, Slovic, and Tversky (1982) for major articles from the decisionmaking literature discussing the problems of assessment of uncertainty and overconfidence in judgment.

[27]Van Creveld (1985).

[28]Farndale (1987, p. 5).

[29]We are reminded of Will Rogers' complaint about a politician: "It's not what he doesn't know that bothers me; it's what he knows that ain't so." See also Quirk (1986).

Focusing on the Wrong Level of Detail

A third cause of inappropriate content arises when the battle is examined from the wrong level of detail. Each echelon requires information at a certain level of aggregation, typically two echelons below itself. For example, information germane to the brigade commander, such as battalion and company status, is too fine grained for the corps commander.

Acting at an echelon that is too low can cause commanders to lose the image appropriate to their own echelon. Their staffs, in turn, focus on too fine-grained information and do not produce the content that is required for the larger picture. Even when the commander and staff share this lower-echelon image, the resulting information exchange runs the risk of being inappropriate to the decisions that are called for. For example, at one exercise we observed, the commander and the G3 became so involved in the intricacies of a difficult maneuver at a subordinate unit that they lost sight of the relationships of that subordinate to its adjacent units. Their demand for information at the detailed level meant that not enough information about other places on the battlefield was processed, and a threat that eventually overtook and canceled the lower-echelon maneuver was ignored until it was almost too late.

Although commanders have a need to "see the battlefield through subordinates' eyes," the temptation not only to see but to act the role of the subordinate is one that many commanders have been unable to overcome.[30] The problem of not looking at a high enough level of aggregation is particularly prevalent at corps and Army Group command posts, where few commanders and staff have had training and education specific to the operational art of warfare. In this circumstance, there is a natural bias to seek detail because past experience makes that level of knowledge comfortable.

There is no set way that information is aggregated for a higher headquarters. On the one hand, each echelon can aggregate its own subordinate units and transmit this information. On another, each echelon could perform the aggregation for the second echelon down. Yet a third way would be to pass the responsibility for aggregation to the unit using the information. It is important that a venue of synthesis be chosen that minimizes any mismatches in level of detail. Aggregating the information at the lower echelon reduces the amount

[30]Van Creveld (1985).

of information that has to be transmitted and reduces the mismatch in level of detail, but not having the raw information at the higher echelon prevents the higher echelon from obtaining detailed information without a time-consuming query to the lower echelon. The resolution of this dilemma lies in identifying multiple locations for repositories of raw data that the staff can call upon to support information requests.

Mismatches in Time and Space

If information flow is to proceed properly, the right stuff has to get to the right place at the right time. That is, information has to get to the right consumers, timed to the consumers' needs, and at a level of detail that the consumer can use. Mismatches in any of these areas will impede proper information flow. What is right and what is wrong is dictated by the commander's image; what is right in one instance is not guaranteed to be right in another. When mismatches occur, the chief sources are internal organizational structure and interdependencies with external organizations.

Timing Mismatches. Each EAB organization typically optimizes its decision cycle to fulfill its own mission. This can have a disastrous result if all echelons of command elect to have their decision briefings at the same time. Following the decision briefing, each command will send its plan to lower echelons. The new plan will arrive at the lower echelon *after* the lower echelon has prepared its own plan for the next-lower echelon, with the result that each echelon will base its daily plan on 24-hour-old guidance from higher echelons. Command and control breaks down as all guidance is overtaken by events; a superior commander can have no confidence that his image will be shared by his subordinate commanders. This timing mismatch problem is not merely theoretical; we observed it at more than one CPX and between more than one set of adjacent echelons. The consequences of the mismatch were minor only if the higher echelon did not change the essence of its guidance within a 24-hour period or if the subordinate commander correctly anticipated the change of guidance.

Location Mismatches. Because of their specialized equipment, education and training, and access, the different staff sections operate in sequential fashion. It is not clear that the time-critical and expensively obtained information passing through standard channels is diverted horizontally to the best distribution of consumers in each echelon's staff organization. For example, one unit's planning cell is

composed entirely of people from the G3 section. When the planners require intelligence information, somebody has to call or visit the G2 section to obtain that information. Adding somebody from the G2 section to the planning cell and charging that person with guiding information from intelligence to planning would probably make the planning process flow more quickly and smoothly for that unit.

Moreover, producers and consumers of information are not the only players in the information-flow game. The communications center is both a powerful asset and a tremendous bottleneck. Many requests for intelligence from higher echelons will be transmitted separately from many different shops within the lower echelon. One large report may come back that contains the requested information as well as the information requested by other organizations. The communications center is ill equipped to determine who might need this collection of information. Even when incoming information has a specific addressee, communications centers are often not equipped to provide delivery service. The intended recipient may or may not know that vital information has been delivered to the communications center, and as we sometimes observed, important information can sit aging in a pigeonhole.

III. IMAGE MAINTENANCE AND MODIFICATION

THE FIVE O'CLOCK FOLLIES

Consider the following scenario, which could occur at any of a number of division main command posts.[1] In it, a division has been executing a holding action for two days with acceptable results. The plan is for the 1st and 2nd Brigades to continue holding position while the 3rd Brigade counterattacks to gain "Objective Denver."

The commander, together with his Assistant Division Commanders (ADCs)[2] and Chief of Staff, enters the room for the 1700 decision briefing. The other attendees are already present. The commander opens the meeting by asking, "Do we have any earthshaking decisions to be made?" The Chief of Staff makes a few summary comments about the events of the last 24 hours and stands aside for the G2 brief. The G2 dismisses the weather update by saying that the weather will be holding as expected for the next 72 hours. He summarizes enemy positions and notes only modest advances made during the day.

The G3 begins his brief by announcing that the 1st Brigade has just encountered enemy use of persistent chemicals adjacent to their defensive perimeter. The commander interrupts and asks the G2 about specific placement of persistent and nonpersistent chemicals. He digs deeper into yesterday's G2 briefing about enemy intent and expresses his concern that the enemy intent to attack in the 1st Brigade sector could not be as predicted yesterday unless the enemy intended to cross his own lines of persistent chemicals. The commander asks for and obtains more weather information specifically oriented toward the effects of the chemical attack. The weather briefer is able to provide only some of the information the commander asks for. Given this new information, the commander asks the G3 about the 1st Brigade's ability to abandon its defensive position along the chemical laydown area and to join the 3rd Brigade in its assault on Denver.

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[1]The scenario, like the planning meeting described above, combines decision briefings from a number of exercises we have observed. None of the events is purely fictitious.

[2]There are two ADCs, one for maneuver (M) and one for support (S).

The remainder of the G3 briefing, as well as the G4, G1, and G5 briefings, proceeds as the briefers had intended. Following the staff presentations, the commander steps up to the map. He says that, given the news of the persistent chemical attack, he no longer views the enemy as intending to force a breakthrough in the 1st Brigade sector. He accepts the risk that the persistent chemical attack may be a deceptive move on the enemy's part. He now believes that it is important to seize Objective Denver as rapidly as possible, and so he wants the 1st Brigade to prepare to join the 3rd Brigade in a counterattack. The ADC(M) is to coordinate the assault. The commander ends the decision briefing by asking if everybody understands what they have to do. There is a general murmur, and the meeting breaks up.

In this decision briefing, we can trace a variety of implicit assumptions that affected the way in which information was transmitted. The G2 believed that he understood the commander's intent and concept of operations well enough to dispense with the weather report. He believed that it had no effect that had not already been considered on the battle. He could therefore streamline the briefing by omitting unnecessary details. The G3 believed that the chemical agent attack constituted a major violation of the commander's image and thus began his briefing with that information instead of holding it back until his summary of each brigade's status. The commander took the news of the chemical attack as invalidating his image of the battlefield and interrupted the normal flow of the decision briefing to reconstruct that image. That reconstruction required information that was not planned to be presented in the decision briefing, only some of which was available. Once the commander was comfortable with a new image, the briefing proceeded normally. The commander ended the briefing by presenting his new image and his new intent. He asked whether or not this image and intent was shared by the staff and interpreted their murmurings as an affirmative response.

THREE MODES OF INFORMATION PROCESSING

The scenario just presented reaffirms the fact that a commander's need for information is framed by his image of the battlefield. New information is continually sought to test and verify that image; if the image remains intact, then the commander can proceed to plan its realization. If, however, information indicates that the image is

flawed, then more information must be obtained to repair or reconstruct it.

The type of information processing that tests the validity or the degree of understanding of an image could differ substantially from that which is used to repair or reconstruct it. The command-and-control perspective presented in this section makes explicit the monitoring activities and makes clear the need to provide the staff with the information necessary to realize when a plan is no longer valid or when resource orders are not going to be carried out as expected. In the "Five O'Clock Follies," the unanticipated persistent chemical attack was an event that took the command post out of mission effectiveness monitoring and back into a mission-planning state. The planning-session example that opened Sec. II illustrated a mission-planning state. Once the planners had constructed a concept of operations that represented the commander's intent, then the command post returned to mission effectiveness monitoring.

In the course of our observations, we identified three distinct modes of information exchange between commander and staff that corresponded to the state of the commander's image and the extent to which the image was shared. We have labeled these modes *pipeline*, *alarm*, and *tree*. The first two modes are, respectively, direct and indirect modes for image testing, while the third allows the commander to probe into uncertain territory to repair or reconstruct an inadequate image or understanding.

Pipeline

The pipeline mode of information exchange is a largely one-way transmission of information that proceeds according to a set order and a set format. Figure 3.1 presents a schematic of the pipeline. Information is provided to a decisionmaker in a set order, and a decision results after all of the information is provided. Time or availability problems may mean that all of the information desired is not transmitted; in that case, the decision is made on the basis of the information that has been obtained. The two most common examples of the pipeline mode of information exchange are the traditional and formal form of the command decision briefing and information passed in standardized charts and reports.

The traditional command-post decision briefing is the embodiment of the pipeline mode. Figure 3.2 presents an outline for a decision

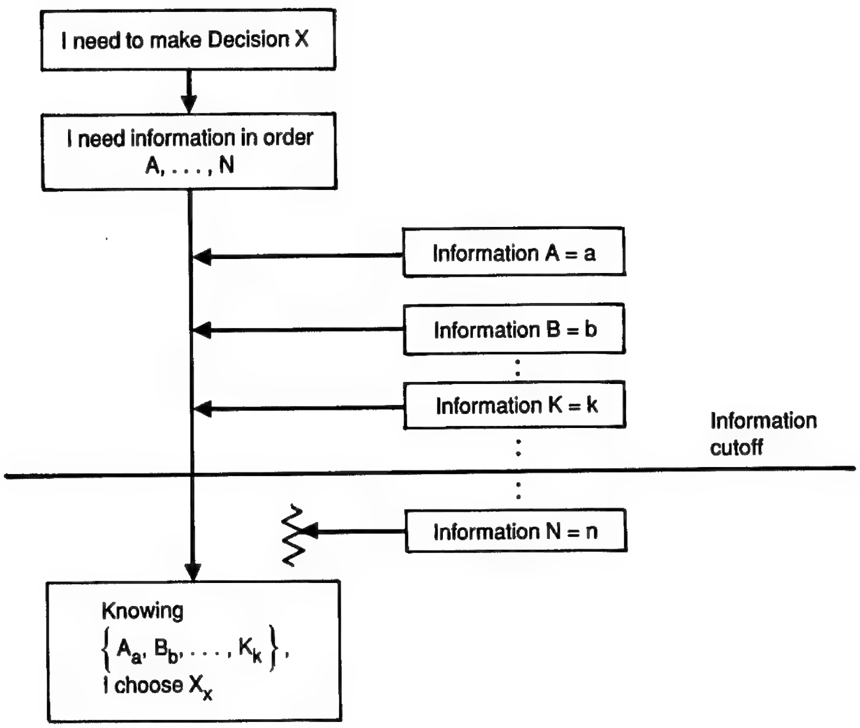

Fig. 3.1—Schematic of the pipeline mode of communication

briefing we observed at CENTAG.[3] The decision briefing, if uninterrupted, would have run for about 45 minutes; usually, it lasted from one to two hours. The pipelined briefing provides the commander and staff with a shared understanding of the situation so that the commander's intent will be heard in the appropriate context. The pipeline is ideally suited to this type of information exchange.

A second embodiment of pipeline information transmission is that represented by standardized forms. Figure 3.3 presents such a form, again taken from CENTAG. In our observations of CPXs, we noted a

[3]Similar outlines were observed at other command posts. CENTAG differs from corps and divisions in that the NATO Fourth Allied Tactical Air Force (4ATAF) is collocated with CENTAG and the decision briefing is a joint one. It is our belief that as AirLand Battle doctrine comes to be implemented, EAB decisions will increasingly become joint.

1. Overall Current Situation
    a. Theater
    b. CENTAG/4ATAF
2. Weather
    a. Influence on operations
    b. Local area
3. Enemy Situation
    a. Ground situation
    b. Air situation
    c. Enemy capabilities
    d. Enemy intentions
4. Own Situation
    a. Ground situation
        i. Actions
        ii. Combat effectiveness, reserve status
        iii. Corps positions, movements, objectives
    b. Air situation
5. Nuclear Operations (if required)
6. Guidance from Higher Echelons
7. Joint Overall Assessment
    a. Near term operations
        i. Logistics, personnel, etc.
        ii. Limiting factors
        iii. Civilian, psychological, etc.
    b. Long term operations
8. Courses of Action
    a. Alternatives
    b. Advantages and disadvantages
    c. Recommendations
9. Decision

Fig. 3.2—CENTAG/4ATAF joint decision briefing outline

NATO SECRET

(WHEN FILLED IN)

INTELLIGENCE REQUEST	CONTROL NUMBER :........................ INITIALS: TIME RECORDED :........................ TIME OF REPORT :..

FROM :..

TO : .... INFO :...

SUBJECT : INTREQUEST :

1. SERIAL NUMBER :

2. PRIORITY :

3. ACTIVITY/TARGET TYPE :

4. ACTIVITY/TARGET LOCATION
   UTM /GEOGRAPHIC COORDINATES :

5. INFORMATION REQUIRED :

6. DATE(s) COLLECTION REQUIRED :
   A. START DATE/TIME A :...
   B. STOP DATE/TIME B :...
   C. FREQUENCY OF COVERAGE/REPORTING C :...
   D. DATE/TIME NO LONGER OF VALUE D :...

7. LOCATIONAL ACCURACY :

8. JUSTIFICATION :

9. SPECIAL INSTRUCTIONS .

10. REQUIRED DISSEMINATION :

11. REMARKS :

CR FORM 6504 (AUG 85)

NATO SECRET

(WHEN FILLED IN)

Fig. 3.3—NATO intelligence request form

lot of people spending a lot of time filling out such forms or hand copying standardized formulas from manuals. When the information to be transmitted (be it a request for intelligence, a course of action, an order, or the results of a decision aid tool) easily fits into a standard format, mutual communication flow is smooth and quick.

The other side of that benefit, of course, is the need to fit into a standard format information that may be inappropriate to that format. Thus, a standardized-form intelligence request will produce standardized intelligence responses; nonstandard intelligence needs that do not easily fit on the form are harder to fill.

Pipelines are particularly well suited to regularly scheduled or highly structured information exchanges. The pipeline style of presentation is ideal when all of the inputs are known in advance and when time is a scarce commodity. The staff can anticipate what information is needed, isolate the relevant input parameters, synthesize and analyze the inputs, and streamline the information presentation. For example, because decision briefings are scheduled events, the staff can prepare more elaborate and thoughtful analyses using more information than if called upon to brief on short notice.

A pure pipeline is inadequate in three circumstances. The first is that in which critical information is not included in the pipeline. Its solution, which involves stuffing the pipeline to the limit, has generated the commonly held perception that command posts are overwhelmed with useless information. The second circumstance in which a pipeline is inadequate arises when the need for a certain type of information turns on the content of the information. On a particular day, for example, a corps commander may not need to know the combat effectiveness of individual brigades unless the brigades are at less than 70 percent. A pipeline is not designed for such a contingent flow of information. Finally, the pipeline is inadequate if the decision's input variables are not known in advance. In less structured decisions, the decisionmaker determines the sequence of information on the spot, reacting to information received with new requests. The pipeline cannot anticipate these sequences in advance.

The first of the three circumstances is the one that has attracted the lion's share of attention; the second two, while equally problematic, have not been as well studied. The latter two circumstances have, however, been unofficially addressed; the alarm and tree modes are ways of communicating the attempt to deal with those circumstances.

Alarm

In our example decision briefing, the G3's interruption of his own intended briefing to tell the commander about the chemical attack constituted an alarm that triggered the commander's expert knowledge about the tactical uses of chemicals. The use of persistent chemicals along a line that he had expected the enemy to attack across signaled the enemy's intent to attack elsewhere. The commander's image of how the battle would unfold had been violated, and his plan was in need of change.

Figure 3.4 shows an abstract form of the alarm information-processing mode. A number of events, some specified in advance and some not, can trigger an alarm. Unless one of these events occurs, no information is transmitted; for example, the commander is not told of all of the places where no chemical attacks occurred. Once an event occurs, the alarm is tripped, and information is sent as quickly as possible. The commander uses this information to decide whether or not to take action. Once the problem has been taken care of, the alarms are reset to await another triggering event.

The alarm mode is not unique to military command. In management science, "management by exception" refers to a style in which leaders leave subordinates alone except in unusual situations. In the computing world, "interrupt-driven" systems perform the normal computational load of task processing and memory asynchronous in

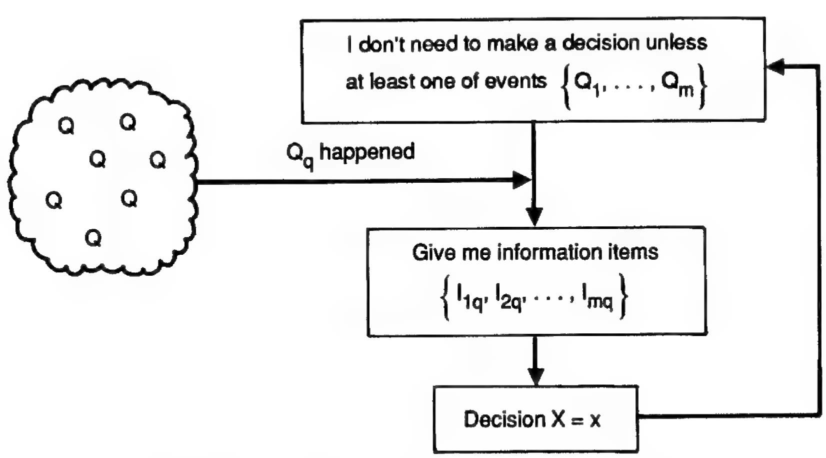

Fig. 3.4—An abstract representation of the alarm mode of communication

put/output devices. After fielding and processing the interruption, they return to normal processing. Alarms are necessary in unpredictable, uncertain, and complex environments.

Alarms may be set explicitly or implicitly. A commander may explicitly inform his staff of certain contingencies or exceptions that will render his plan unsuitable. He is thus setting parameters for alarms for his staff to process and expects to be notified upon the occurrence of such events without regard to scheduled briefing times.[4] An example of this is the system of setting Priority Intelligence Requirements (PIRs). Along with the list of PIRs is often a set of possible answers that would require the immediate attention of the commander.

Parameters for alarms may also be set implicitly by virtue of shared military experience. But alarm information need not be solely about crises; it need only represent a significant departure from that which is anticipated. For example, the commander should be notified of a breakthrough or an exposed flank whether or not he explicitly set an alarm. In one exercise, a staff member updated the commander on the way to the mess hall with some new intelligence about enemy troop movements because that staff member (correctly) believed that the general would want to receive this information as soon as possible.

The problem of alarm communication lies not in the transmission of the alarm-triggering event but rather in the identification of any event or set of events as alarm triggering; once an alarm has been recognized as such, it is almost always communicated to the commander quickly and accurately. Implicit and explicit alarms are difficult to automate because all possible contingencies cannot conceivably be identified in advance. The key to successful alarm mode rests on whether the commander's image is shared; only then can the system respond appropriately to image-violating events. This in turn means that the commander must know whether subordinates understand and share his image so that he can determine whether or not his alarm communication system is functioning properly.

Tree

When the persistent chemical alarm alerted the commander to the fact that the image under which his extant plan was created had

[4]Indeed, part of a pipeline information transfer is frequently the definition of possible alarm situations.

ceased to be valid, he required information that was not part of the planned decision briefing. He asked a variety of questions intended to bring his image of battle back into synchrony with the newly acquired information and used that new information to replace part of his previous image with a new part consistent with the totality of that information.

Figure 3.5 presents an abstract tree. In it, the commander needs to make decision X (e.g., to decide on where to allocate close air support). He first obtains information A, which might be the location of a certain enemy unit. The result may be a "show stopper," or information that determines his course of action (e.g., the enemy unit is about to exit a mountain pass). This is shown as response $a = 2$ to information request A. Alternatively, the result may tell him that he needs to make decision Y (e.g., whether or not to commit his reserve division) before he makes decision X. This is shown as response $a = 3$ to information request A. The more typical cases, shown as responses $a = 1$ and $a = 4$, indicate that the *next* piece of information needed is dictated by the response to previous information requests.

The tree mode is an inquiry-based demand-pull approach to searching for and acquiring information. It is demand-pull in that the decisionmaker makes demands on the information system and pulls information from it. In contrast, a supply-push system pushes whatever information it has toward the decisionmaker without waiting for a demand. The prime determinant of information exchange is the expertise that lies with the commander, not the contents of the information system.

Tree mode is necessary in context-dependent situations. Since the amount of possibly relevant information is voluminous and cannot all be effectively presented in pipeline mode, direct requests for information must replace automatic supply. The requests are dependent on the particular situation, the commander's image, his expertise, any alarms that may have been triggered, and the answers to previous requests.

In the past, tree-mode information processing and implicit alarms were the exclusive province of a commander's select aides and liaison officers, as indicated by Griffin:[5]

> The "Directed Telescope," or more specifically, the use of specially selected, highly qualified and trusted young officers as special agents

[5]Griffin (1985, p. 1).

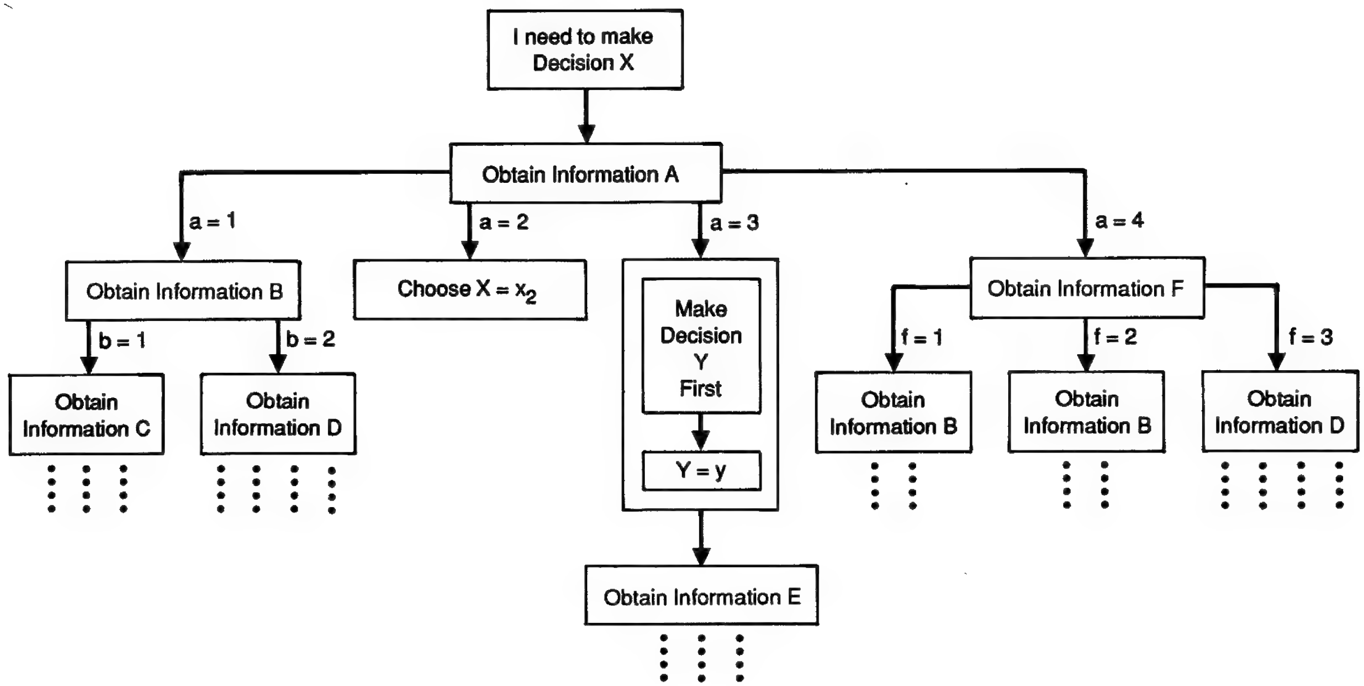

Fig. 3.5—Schematic of the tree mode of communication

> or observers for the commander, has been a fundamental method of responding to this inveterate challenge [for detailed and specific information]. These young officers have been popularly referred to as the "eyes" of the commander . . . . The utility of these "special agents," whether they be aides, liaison, or special staff officers, has been proven in war after war for thousands of years.

Griffin continues by providing examples of successful commanders, including Alexander the Great, the Duke of Marlborough, Napoléon, Grant, Lee, and Patton, who used these officers in what we term the tree mode of information processing.

Pure tree mode is hard to implement a priori either by a staff or by an automated information system. This is because the "bushiness" of even simple decision trees makes them difficult to specify and because commanders normally "look ahead" only a few nodes.[6] Advances in interactive computer systems, plus the circumstance that different "branches" of the tree may lead to the same "leaf nodes," make the problem more tractable; menu-driven systems such as the MCS have many treelike characteristics.

COMPARISON OF PIPELINES, ALARMS, AND TREES

The three modes of pipeline, alarm, and tree are not conflicting processes; ideally, they are integrated parts of a larger information system. The greater speed and distances of the modern battlefield necessitate that pipelines, alarms, and trees be integrated; even if aides in the field act as the "eyes" of the commander, they must now report to the commander electronically if their information is to be timely. If it is to fully support all three modes of information processing, the system must increasingly become a demand-pull/supply-push hybrid.[7]

Which information mode is dominant at any given time depends on the needs of the commander; when the commander has what he believes to be a valid image and believes that his subordinates understand that image, then the system will be in pipeline mode. If,

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[6]The practice of looking ahead only a few nodes is not an indication of poor decisionmaking skills on the commander's part. In the absence of the ability to analyze completely (either forward from the present position or backward from desired outcomes), experts decide on the basis of assessments of a small number of likely alternatives. One should consider in this regard the strategy of the world chess champion of the 1920s, José Capablanca. When asked how many moves he thought ahead, Capablanca replied that he thought only one move ahead, but the best move.

[7]In Sec. IV, we present a more detailed specification of such a hybrid system.

on the other hand, an event that potentially disrupts the image occurs, then the system moves to alarm mode. Tree mode is used to rebuild an image or to establish understanding between commander and subordinates. Each mode, when dominant, differs in the quality of the information it delivers and in the demands that it makes on a command-and-control system. In this subsection, we discuss those differences.

Using Information Modes

Which mode of information exchange is employed is closely allied with the commander's assessment of the battle image, as shown in Table 3.1. As long as the commander does not have cause to question this image, he is in either a pipeline or an alarm mode of information processing, depending on whether he is actively or passively acquiring information. In these modes, his primary need is for information that will validate or invalidate his image (in binary fashion). In an ideal sense, if the commander could teach his staff just what is inside his mind, the commander would need no additional information during the execution of his plan unless something inconsistent with the image emerged. But because that ideal cannot be achieved, the commander has set up a system with which to obtain validity checks. When the commander has reason to question the validity of his image, he changes to a tree mode of information processing. The actual items of information the commander needs depend on the image the commander is trying to construct, the reason the old image became invalid, and what can be known about the situation. The important concept here is that the commander's information requirements are developed sequentially as new information is obtained.Information Mode and Quality of Information

The information that is exchanged in the three different modes differs in time value, level of detail, and degree of uncertainty. Those differences are summarized in Table 3.2.

Timeliness. The pipeline mode of information exchange is most often found in regularly scheduled decision briefings. These briefings, which typically occur every 6 to 24 hours, are scheduled according to a decision cycle that synchronizes unit operations. The time value of information is secondary to the maintenance of synchronization. The events that trigger alarms are asynchronous with normal organizational operations. The information content of an alarm must reach the right people in a manner timely enough for someone in authority to decide whether the new information warrants unplanned

Table 3.1

FUNCTIONS AND APPLICATIONS OF THE THREE INFORMATION MODES

Mode	Applications	Functions
Pipeline	For "normal" operations When the commander believes the image is valid For the continuation of the plan	To ensure that staff and subordinates share the commander's image To check the validity of the image
Alarm	For "normal" operations When the commander believes the image is valid Between regular information conveyance times	To alert the commander to a possible violation of image To alert the commander to a possible transition to tree mode
Tree	When the image is broken When a new plan is being constructed	To repair and reconstruct the image To begin a new plan

action. When information that is potentially an alarm reaches a subordinate, that person must decide whether to shift to alarm mode by causing a nonscheduled information transfer or to remain in pipeline mode by holding the information for the next scheduled transfer. Knowledge of the commander's image is the most important requirement for making that decision appropriately.

Clear assessments of the time value of information cannot be made with respect to tree mode. A decisionmaker can ask about a piece of information and be satisfied if it is presented at the next briefing, or he may be unable to proceed with his situation assessment without the vital piece of information requested. The time value of the information varies with the information item and with the situation.

Table 3.2

INFORMATION MODE AND THE QUALITY OF INFORMATION

Mode	Timeliness	Detail	Uncertainty
Pipeline	According to schedule (typically 6 to 24 hours)	Aggregated (typically two echelons down)	Moderate
Alarm	Immediate	Highly detailed, highly focused	Likely to be very high
Tree	Varies with item and situation	Selective use of "telescope"	Likely to concentrate on lower-uncertainty items

Level of Detail. Like the timeliness of information, the level of information detail differs according to the mode of information Table exchange. During a pipeline briefing, a commander expects to have a picture painted in broad strokes of his unit and of subordinate units down two echelons. Information beyond two echelons down is usually too detailed for command-level decisionmaking. Alarms, by contrast, are often highly detailed. A division-level alarm may even be the report of one man observing three tanks along a tree line where no known enemy activity had previously been reported. The level of detail of information exchanged in tree mode is determined by the commander's requests and may be highly aggregated or as detailed as it is in alarm mode. From the staff member's point of view, tree mode requires the possession of great detail because the staffer must be prepared to present information at many different levels of aggregation.

Uncertainty. Pipelines contain information about which an information system feels confident, whether or not that confidence is warranted. Because the scheduled flow of information in pipeline mode usually provides the opportunity both to verify intelligence and

to perform thorough analysis, the degree of uncertainty is typically only moderate.[8]

On the other hand, an alarm, which by definition conveys unexpected information, can be quite uncertain. This is because alarms are typically triggered by unreliable pieces of information that emerge from places where the war is foggiest. For example, at a recent CPX, a division received a report that one of its brigades had been unexpectedly attacked by five enemy tank battalions and had been reduced from 60 percent to 10 percent of its strength. Subsequent information revealed that although five tank battalions had been sighted, only two had entered combat, and the brigade had been reduced to 40 percent strength. The original report, erroneous as it was in terms of the enemy action and results, still contained the essence of what was important to the commander: a major maneuver unit had been unexpectedly attacked and had suffered serious losses to the point of combat ineffectiveness.

When tree mode is being employed, a commander is more likely to concentrate on information that is relatively certain. This is because he is in the position of constructing or reconstructing his image of the battlefield and is ascertaining what is known. That is, if the commander believes that answers to specific questions are not available, he will task subordinates to obtain that information but will also abandon that line of inquiry for the present and move on to another. If, on the other hand, information appears to be available, then the commander will explore that line of inquiry in an effort to expand his understanding. As a result, the give-and-take of tree mode will tend to concentrate on what is known rather than on what is uncertain.

Information Mode and Demands on the Command-and-Control System

The need to support the three modes of information exchange imposes demands on the underlying command-and-control system. In order to support the commander and his staff in all three modes, the command-and-control system must be able to determine what information should be sent and when that information should be sent;

[8]"Moderate" here means about as little uncertainty as one can reasonably expect in the inherently uncertain battlefield environment.

it must also be able to query a large and diverse universe of information.

Table 3.3 shows the demands of the different modes on the command-and-control system. The rule for *when* to send information from the staff to the commander is rooted in the mode of information exchange and is tacit. Information will be pushed toward the commander according to a predetermined schedule in a pipeline. Alarms are sent as soon as they are detected, and their importance is known. Tree mode requires an explicit demand-pull from the commander. The staff, acting as part of the command-and-control system, understands and supports these rules; in effect, they determine which of the modes applies at any time and how the modes mesh, given the situation. The electronic parts of command-and-control systems are not so flexible at present, nor are they likely to become so in the future.

In pipeline mode—e.g., in a decision briefing—a formula determines in advance *what* information will be presented to the commander. The occurrence of unexpected events will determine what information will be exchanged in alarm mode. The information that the command-and-control system provides in tree mode is dictated by the commander's requests.

A commander may need an extensive *volume* of information to make the many decisions he faces in combat. In pipeline mode, the formula that dictates the content of the information also bounds the volume of data that is exchanged. Alarms by definition come from outside the moderate domain of pipeline information. In essence, any part of the battlefield information system can trigger an alarm, so the potential universe of query is quite large. However, information is actually sent only when the alarm is triggered, so the actual volume of information received is quite small. In tree mode, the commanders can query a fairly large universe of information, and extensive ability to respond to queries must be made available. Thus, the volume in tree mode can be large in terms of both potential information needed and actual information transmitted. A command-and-control system based on the universe of information queried to form a decision brief would not be sufficient to accommodate information exchange of the form caused by alarm and tree modes.

Table 3.3

INFORMATION MODES AND THE COMMAND-AND-CONTROL SYSTEM

Mode	Rule Determining What Information to Send	Size of the Universe of Information to Be Queried	Rule for When to Send Information
Pipeline	By predetermined formula	Moderate	Push supply according to schedule
Alarm	By occurring events	Large	Upon detection
Tree	By request	Very large	Demand-pull

PROCESSING MODE AND THE COMMANDER'S IMAGE

The image-building and action elements portrayed in Fig 2.1 can be abstracted into two cycles each.[9] Information concerning image building is concentrated on two EAB command tasks:

- *Mission planning*—i.e., searching for and selecting a plan that is expected to achieve the objectives; and
- *Mission effectiveness monitoring*—i.e., continually reassessing the suitability of the promulgated plan.

The action element is similarly composed of two control tasks:

- *Resource-order generation*, or the construction of resource orders that are expected to give rise to the demanded resource activity; and
- *Compliance monitoring*, or determining how closely the demanded activities are being, and will be, achieved.

[9]Galley (1985).

Figure 3.6 shows the relationship between the pair of cycles and the information mode used in transiting among states. Mission planning is a complex iterative process that relies heavily on the tree mode of information search and exchange. Once a plan is constructed, it is promulgated via standardized pipeline modes, and the system transits to both mission effectiveness monitoring and resource-order generation.

Mission effectiveness monitoring typically uses pipeline modes of information exchange. If monitoring reveals that the commander's image is no longer valid or that the plan is in need of revision, then an alarm is triggered that sends the system back to mission planning.

The promulgated plan is translated by the staff into a set of resource orders. The resource-order generation process is, like mission planning, an iterative one that requires the use of tree mode. Here, however, the information exchange is typically among staff members rather than between commander and staff. If, during resource-order generation, it becomes apparent that the staff does not adequately understand the commander's image, then the commander intervenes within the resource-order generation stage to set matters straight. Resource orders are transmitted via standard pipelines.

The resource-order compliance-monitoring stage assesses how well subordinates (e.g., lower-echelon commands) and resources not under direct control (e.g., intelligence assets) comply with the plan. This monitoring is generally supported by pipelines, supplemented by alarms. Depending on its severity, an alarm will send the staff back either to generate new resource orders or to perform mission planning.

INFORMATION FLOW AND PROCESSING MODE

The directionality and duration of information exchange vary widely according to information mode. A pipeline has a slow, deliberate nature that is intended for the monitoring of a large complex image. An alarm has a provocative, intense nature with a duration of unpredictable length between information request (setting the alarm) and response, but a very short duration response when the alarm is triggered. A tree is an interactive, exploratory activity that requires a short response time.

Although the pipeline mode is nominally used for collecting and reducing information to present to the commander, we found that, particularly in decision briefings, it had the purpose of *disseminating*

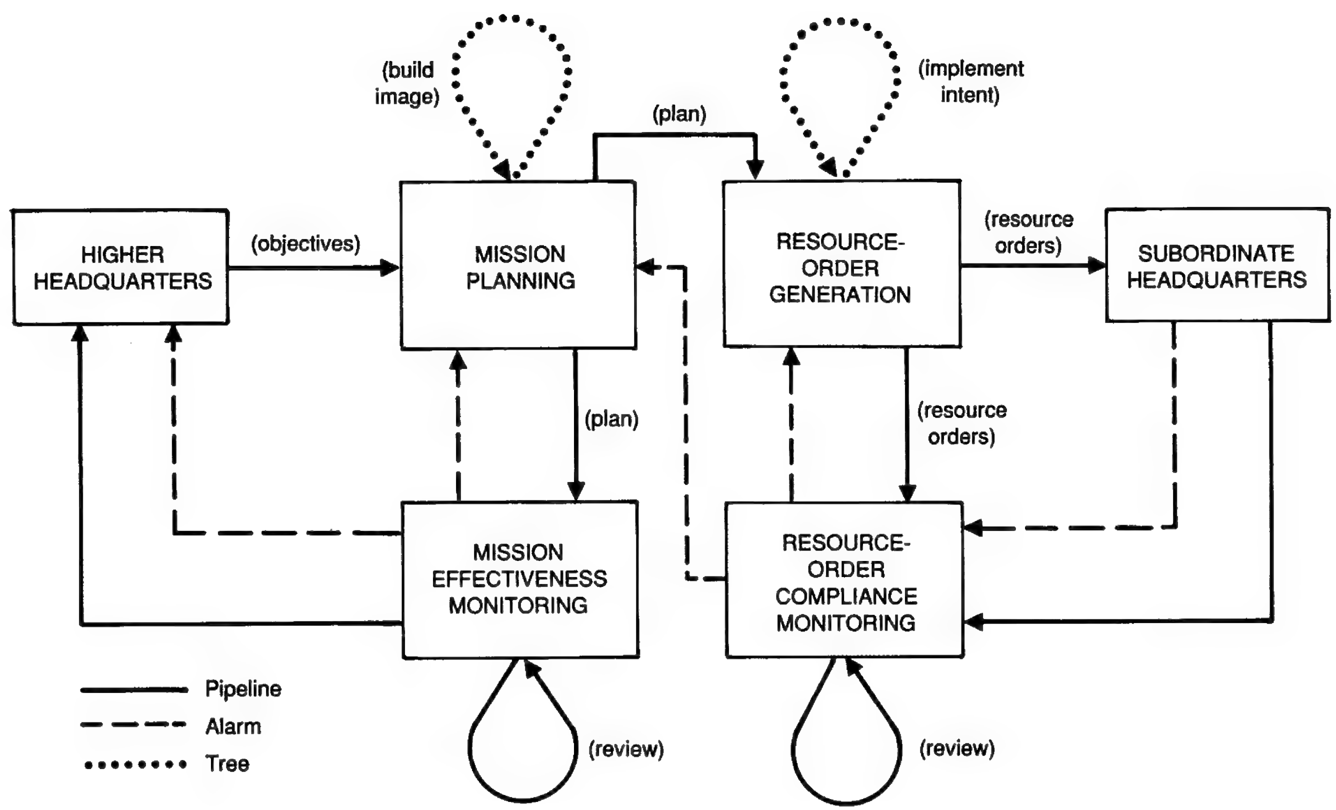

Fig. 3.6—Information mode and command-post tasks

images; the briefing's main function is to ensure that the commander's image and the information that contributed to the image and plan are shared by all. Much of the information presented in the decision briefing is the product of synthesis and lengthy analysis. Input information feeding into the briefing, both from above and from below, must arrive in synchrony with the decision cycle so as to fit into the analytic preparation for the briefing.

In contrast to the dispersive purpose of pipelines, alarms focus critical information upward to decisionmakers. It is critical that alarm information flow to the right place for the event to be detected and subsequently acted upon. Although alarms are simple in concept, they can fail when the commander's image is not shared because they are not recognized as necessitating a change of plan. The explicit *setting* of alarms is a pipeline activity, but many alarms are set implicitly via the image shared by the commander and his staff.

Tree is the most interactive and iterative mode of information exchange. It is composed of a series of information requests flowing from the commander and data flowing back to him. Assessments are made as new data are supplied; these assessments in turn determine new information requests. Assessments and options flow from commander to staff and from staff to commander.

IV. INFORMATION TRANSMISSION, DISTRIBUTION, AND STORAGE

INFORMATION DELIVERY SYSTEMS

One of the stimuli for the present study lay in the popular observation that command posts suffer from information overload. The picture was drawn of a TOC hip-deep in computer output, with the commander tearing his hair out because he couldn't find the precise piece of information he needed in the pile.

Our picture is somewhat different. Command-post staff information needs are highly dependent on the specifics of the commander's concept of operations, his desired courses of action, and his intent—i.e., on his image. The task of obtaining information is therefore not one of specifying particular needs, but rather one of considering the boundaries of what information the commander might need and from whom. That is to say, there should be a well-defined path for obtaining any information item that the commander or his headquarters staff might want.

On the surface, both pictures regard the supply-push nature of the CCIS as the source of the problem and offer demand-pull as the solution. That is, both views hold that a CCIS should be able to manage top-down requests for information specifics where different "processors" can make demands on the same set of "gatherers."

As we saw in the previous section, however, pipeline and alarm modes require a supply-push data flow orientation, while tree mode requires a demand-pull. This suggests that consideration only of the nature of information *flow* does not take into account the entire picture and that replacing supply-push with demand-pull might not be the correct solution. In this section, we examine the CCIS from two perspectives: information *flow* and information *storage* (see Fig. 4.1). A discussion of the extreme cases of each dimension leads to a description of the properties of that dimension. The relationship between those properties and the three information exchange modes leads to an understanding of tradeoffs sufficient to motivate a hybrid system that supports all three modes.

In our discussion, we abstract a CCIS as a set of processing and collection resources coupled by information paths. Some examples of

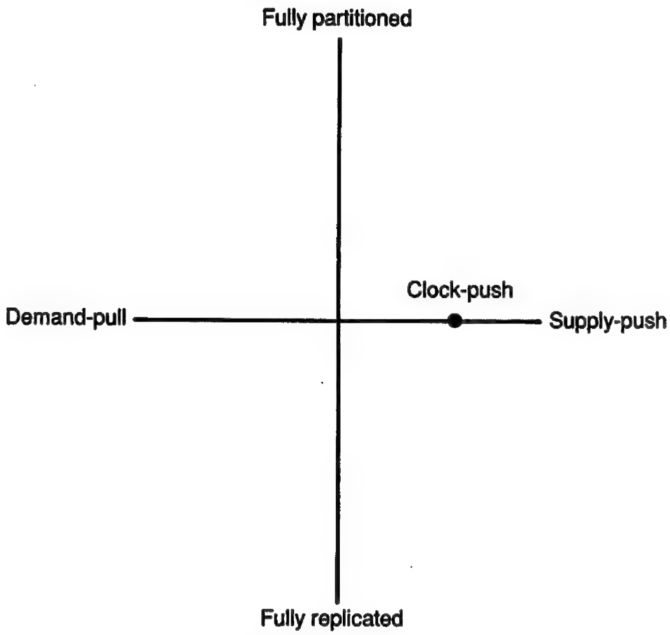

Fig. 4.1—Information flow and storage dimensions

collection and processing resources may clarify the distinction between the two. Sensors are obvious examples of collection resources and are found at the fringes of the system. The information produced by sensors may be processed, for example, by a sensor fusion center or by human analysts at the command post.

The G2 is an example of an information processor; he both consumes and produces information. In relation to sensors and sensor fusion centers, the G2 is a consumer of information; in relation to the G3, the Chief of Staff, and the commander, he is a producer of information. The information thus produced is typically of a higher level of aggregation than that of the information consumed.

THE INFORMATION FLOW DIMENSION

A military information system might be likened to an urban electrical power system. Between the generators that produce electrical power and the appliances in our homes that consume that

power, there is a vast distribution network of cables and transformers. This system, when operating normally, pushes only the power we need into our homes when we need it. We do not expect any delay for the power company to turn its generator up between the time we turn on the switch and when the vacuum cleaner starts. We expect the transmission and distribution network to be in place and of sufficient capacity to support a wide spectrum of demands and to provide power for uses we haven't yet imagined.

Like the electrical power system, a CCIS produces, transforms, distributes, and consumes the wattage of information.[1] Unlike an electrical power system, however, a CCIS will sometimes push more information to the consumer than he can handle or will delay delivery while the needed information is gathered to meet the demand.[2]

The orientation of the Army's present electronic and human command-and-control system is one of pushing a supply of information toward the command post and subsequently toward the commander. This *supply-push* orientation supports the decision briefing and regularly scheduled analytic chores that use a pipeline. It also supports, to the extent that they can obtain priority, the transmission of identified alarms. It adequately supports neither the setting of alarms nor the tree mode, both of which require a *demand-pull* orientation.

Pure Supply-Push Systems

In discussions of information flow, systems are customarily characterized as either information driven or demand driven. If the availability of input information triggers processing and collection resources into action, then the system is said to have an information-driven nature. If, on the other hand, the processing and collection of resources are triggered by an external demand or request, the system is considered demand driven.

As an example of a pure supply-push subsystem, consider the information flow from an intelligence platform to a sensor fusion center. This information exchange and processing is information driven. As the sensor information arrives at a nearby collection

[1]The analogy is limited in an important respect: as far as an appliance is concerned, one watt is as good as another, but the same fungibility rarely exists among items of information.

[2]In this analogy, we do not touch on the additional problem of a CCIS having an enemy who is trying to destroy, disrupt, or delay the system. The problems of "unimpeded" functioning are sufficiently great.

station, it is pushed to the fusion center for processing. The processing resources are triggered into action when all the required input information is provided or available; no other control or synchronization is required. The characteristics of such an *information-driven* system are summarized in Table 4.1.

Purely information-driven supply-push systems have simple control mechanisms and can be extremely fast. The mechanism controlling information processors is wholly contained within the processor, which kicks into action if and only if—and as soon as—all necessary input information is available. Correspondingly, the output information is produced and can be transmitted to eventual consumers at the earliest possible time. However, an expensive processor may remain idle for long periods of time awaiting input.

Some collecting and processing resources must operate in an information-driven way. A radar device, for example, simply cannot operate in a demand-driven style; its purpose is to scan the sky continuously and to push the information it obtains to a processor. The processor then transforms the input data into usable forms, such as a display for a human consumer or a digital record that can in turn be analyzed by a computer.

Table 4.1

CHARACTERISTICS OF A PURE INFORMATION-DRIVEN SYSTEM

Advantages	Disadvantages
Information is transmitted at the earliest possible time	Many resources can process information that might never be used
Processing resources operate autonomously (no complex and slow centralized control)	Collection resources must be allocated to all possible information sources
	Processing sources must be allocated to all possible processing tasks
	Critical information can be lost in a mass of data

Although the supply-push system can be quite fast, it rarely represents an optimal allocation of collection and processing resources. Since information is constantly streaming into it, the sensor fusion center will be perpetually busy processing information even if the product is never used. Therefore, it is possible that the processing and collecting resources could have been employed more productively on some other information-processing task.

Problems with supply-push are not restricted to intelligence information. Although a higher headquarters (e.g., a corps) typically does not require fine-grained information from each of its subordinate units (e.g., divisions and separate brigades), there are instances in which that detailed information is necessary. But the CCIS cannot support the transmission of all the detailed information from each subordinate unit; this information must be sent only upon demand. Put another way, in a pure supply-push system, the commander's telescope becomes inoperable.[3]

The use of an effective supply-push system is predicated on the system designer's ability to anticipate information needs and to configure the system accordingly. Effective employment of such a system also rests on the system operator's ability to recognize changing information needs and to reconfigure the system appropriately. There is a certain capital investment in configuring the system. For information with a high probability of demand—e.g., the basic standard information of METT-T—that investment is warranted. But even if the high-likely-demand information is provided, not all of it will be needed at any one time. If all of the high-likely-demand information is pushed regardless of demand, the result is information saturation. Almost paradoxically, saturation leads to information starvation if the wrong instead of the right information is assimilated. Provision of the wrong information can be avoided in a supply-push system only if near-perfect knowledge of the commander's needs can be anticipated in advance and understood on the fly.

Pure Demand-Pull Systems

In contrast to pure supply-push systems, a pure demand-pull system does not rely on the ability to anticipate information needs. It is at rest until a demand is made on it. A specific demand made on the G2, for example, will be translated into a series of demands made

[3]Van Creveld (1985).

on lower-level resources, resulting in another series of demands. This phenomenon is termed a "demand cascade." Each intermediate processing component affected by the demand cascade will remain idle between the time it receives the demand and passes it on to subordinate processors and the time it receives a reply. Only after all of its demanded inputs have been supplied will it be productively applied. Thus, the time between the original demand and its satisfaction is a worst-case sum of the processing times of the involved processors all the way down to sensors supplying primitive inputs plus the communications delays up and down the system.

Figure 4.2 shows a skeletal CCIS network. Inside the command-post (i.e., from the G2 horizontally and vertically up), communications

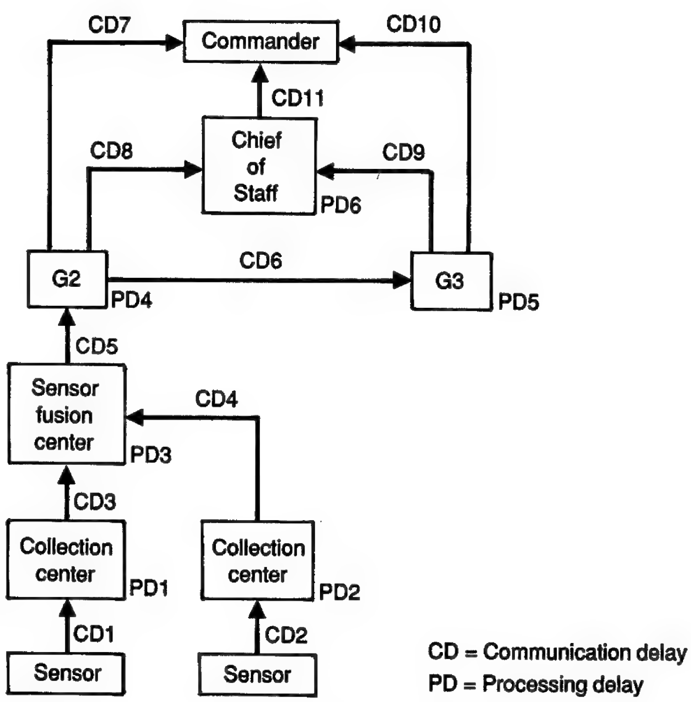

Fig. 4.2— A portion of CCIS net

are largely face to face; outside the command post, electronic media of various sorts are employed. The time penalty of the demand cascade is approximately twice the communications delays shown on the arcs (twice because the demand must trickle down the system and the are must trickle back up) plus the sum of all processing delays associated with each information-processing cell. It isn't difficult to imagine how serious this time penalty is in the context of a real CCIS network.

The characteristics of a demand-driven system are summarized in Table 4.2. In a demand-driven system, processing resources are triggered into action by an external demand or request. Data needed for processing may often be available, but some input may be necessary for the completion of the processing. If input data are missing, then the processing resource either invents them or makes a demand on another resource to produce as output the missing piece of input.

Unlike a supply-push system, which employs processing cells constantly, the demand-pull system has processing cells that lie idle between demands. It is possible to exploit these idle processing cells by rendering them capable of satisfying more than one demand. If processing tasks are assigned wisely, it is possible for a demand-pull system to satisfy the same set of demands as a supply-push system at

Table 4.2

CHARACTERISTICS OF A PURE DEMAND-DRIVEN SYSTEM

Advantages	Disadvantages
Resources produce and transmit only necessary information	Powerful and expensive collection and processing resources are idle much of the time
Collection resources can be allocated according to priority of needs	Time delays occur after the demand is made while information is collected and processed
	Processing resources are under complex external control

far less cost. A much narrower communications bandwidth is required because only needed results are transmitted.

A demand-pull system is attractive because it can allocate scarce resources to those tasks that the commander demands and can then produce only the information that the commander needs. Pure demand-pull systems naturally regulate the volume of information flowing to the commander; only requested information is produced and transmitted. Limiting of information flow is attractive to the command post that has limited collection and processing resources, limited communications resources, or the potential to be overwhelmed with huge volumes of information.

The advantages of a demand-pull system are purchased at the expense of time; satisfaction of demand occurs after the demand cascade trickles down and back up through the information system. The time delay between a demand and its satisfaction may be so great as to obviate the value of the produced information. Additionally, if demands are not made on the system, valuable collection and processing resources lie idle. Those resources might have been applied to some other task in anticipation of a demand, thereby reducing time delay.

The fact that a processing cell is controlled by an external agent (namely, demands made by a consumer) means that the cell lacks the information or the authority to productively apply itself. This is particularly costly in a hostile environment with intermittent communications among cells. A consumer served by a supply-push system perpetually producing and transmitting information will always have the most recently produced information to fall back on in the event of communications failure between the producer and consumer. A consumer served by a demand-pull system that is sitting idle while waiting for a demand will find itself cut off from information in the event of communications failure.

The Present CCIS System

Of course, no real CCIS is either pure demand-pull or pure supply-push. If we choose, we can view the existing system as supply-push, ignoring the origin of the demand for information, or as demand-pull, with the demands having been anticipated and designed into the system. Perhaps the best simple characterization of the current system is one of *clock-push*. In a clock-push system, the demand for information is anticipated, information flow is configured from the ultimate producer to the eventual consumer, information-processing

times and communications delays are estimated, and information is subsequently clocked through the system in time for important decision meetings or analysis.

Clock-push is more akin to pure supply-push than to pure demand-pull (see Fig. 4.1) and seems to have been designed with a pipeline mode of information exchange in mind. Shifting a CCIS clock-push configuration toward demand-pull is unsatisfactory because benefits for tree-mode communication are gained at the expense of costs to pipeline mode for a likely net gain of next to nothing. Rather than compromise along the single dimension of information flow, we must look at another dimension for the desired improvements needed to support tree and alarm modes.

THE INFORMATION STORAGE DIMENSION

The command post cannot afford to be isolated from the information network. Collecting and processing resources and the communications paths that connect them with the command post all exist within a hostile environment; any component can fail at any time. Just as a hospital employs battery backups and portable electrical generators, so can a command post provide itself with a stable alternate source of information in the event of primary information source loss. The analogue of a battery backup is a distributed human or computerized data base; the analogue of a portable generator is a local information-processing capability that can produce more highly aggregated information from raw data in the data base. Like a portable generator that does not produce as much power as quickly, cleanly, and efficiently as can a large turbine generator, the local information processors perform at a level lower than that of the dedicated processor, but under local control.

Instead of pushing a supply of information solely to a consumer, the local information processor can copy and store part of the information in a local data base. Later information demands can then be satisfied from the local data base if the primary information source is unavailable or if the time delay to and from the primary information source is unacceptable. Because nonscheduled information demands are likely to be made in tree mode, this storage should have the capacity to deliver both detailed and aggregated information. This suggests that the data base should contain lower-level information and should be accompanied by local processing capacity to perform aggregations.

We do not suggest that every command post maintain complete and exact copies of all information within the command hierarchy, nor that each command post have the ability to replicate all of the specialized processing currently performed by dedicated processing centers. We do point out, however, that the command post is not merely a place for information to flow into and out of; it is also a repository of information that can be accessed when external flow is inhibited and analyzed when specific information is needed without delay.

A data or information base is distributed throughout the command-and-control information system. How the information is distributed determines how well the information will serve the producers and consumers within the system. Storage can be defined along a dimension anchored at one end by *fully replicated* information bases and at the other end by *fully partitioned* information bases (see Fig. 4.1).

Fully Replicated Information Bases

At one extreme of the information storage and distribution dimension is the fully replicated information base. At this extreme, every storage site within the system has its own complete copy of the information base. Every producer and consumer of information is guaranteed rapid access to the information base because each information processor is collocated with an information base and does not have to compete for communications bandwidth or suffer communications delays.

The primary cost associated with fully replicated information bases is keeping all copies updated. Every time a producer of information updates a local copy of the information base, all the other copies immediately become out of date. One alternative solution to that problem is to immediately update all other copies of the information base within the system whenever a change is made; another is to accept the fact that information bases may disagree between the times of periodic system-wide updates. Any update consumes vast amounts of communications bandwidth even if the information base is small, so frequent updates threaten to swamp the system.

Another important cost is space. Each additional copy of the information base quickly consumes limited storage resources. The only solution to this problem is to purchase more storage space.

Fully Partitioned Information Bases

Fully partitioned information bases lie at the other extreme of the distributed-information-storage dimension. Producers and consumers in the command-and-control hierarchy are clustered together according to some criterion, perhaps by their common need to access the same subset of the information base. These clusters of producers and consumers are connected to other clusters by a communications network. The information base is partitioned in such a way that each piece of information resides in exactly one location.[4] The partitioning is performed so that information that is most often accessed by a specific cluster of producers and consumers is collocated with that cluster. Generally, processors will have a high volume of access to collocated information and infrequent need to access some piece of distant information. Thus, information is generally sent via supply-push to a designated storage and via demand-pull to all other potential users.

The advantages of fully partitioned information bases are that (1) they require far less storage capacity than a similarly sized fully replicated information base; (2) there is no need for massive and costly updates of all copies, as is the case with fully replicated information bases; and (3) if the partitioning is done wisely, most producer and consumer accesses to the information base can be satisfied by the local partition. The cost is that access to remote partitions, even though infrequent, may not be timely or, if communications are interrupted, may not be possible at all.

HYBRID SYSTEMS

Real-world systems are, of course, neither purely demand driven nor purely information driven; nor are they fully partitioned or fully replicated. An optimally configured CCIS is a hybrid mixture of components taken from the two dimensions of information flow and information storage. To determine an appropriate mixture, we consider how the three modes of information exchange support the need to share an image of the battlefield.

[4]If all of the information lies in a single location, then we speak of a *centralized information base*; here we consider a centralized information base as a partitioned base with only one partition.

Topping Trees

In tree mode, a commander asks questions of varying levels of aggregation. Requests for highly aggregated information are typically satisfied locally, but requests for very fine grained information may cause a demand cascade, with its associated unacceptable time delays. To eliminate some of these time delays, information of varying degrees of aggregation can be stored locally with the aim of meeting a quick turnaround time and leaving the clock-push pipeline intact.

In tree mode, information that may be of later use can be stored in a short-term retrieval location.[5] If the information is subsequently needed, one can retrieve it without having to query outside the command post; if the information is not needed, it will vanish when updated. In short, a good hybrid system should have supply-push to the data base and demand-pull from it. Demanding information from a local data base does not incur the excessive communications delays associated with having the information redelivered from the primary source.

Information that the staff believes likely to be requested can be processed in advance, while other information can be processed from stored data upon request. Information transfers often terminate in hardcopy that is distributed to consumers. Thus, information is not in a form that is easily forwarded, displayed, cross-referenced, or browsed. The command post's information storage facility could be organized to provide those services. This need not be a new facility but could instead be an information storage and retrieval requirement imposed on a cell that currently has the responsibility to consume and produce the same information. Perhaps communications centers should be designed and operated as communications and information centers not unlike the Navy's shipboard Combat Information Centers. The question of the level of aggregation with which to store information can best be answered through consideration of the specific battlefield situation.[6]

In the hostile environment in which collecting, processing, and communications resources exist, there is leverage to be gained from anticipating failure and providing redundancy. If information is remembered in more than one place, then the organization that relies

[5]This location could be considered the electronic equivalent of the briefer's back pocket.

[6]Again, the importance of staff (even several removes from the commander) understanding his image is underscored.

on it can be more tolerant of single-point failures assuming that redundant processing capability is also provided. If local storage is lost, an organization is not prevented from performing its tasks, but its performance is degraded by the time that is needed for local processing capability to access remote information. Alternatively, if primary information sources and specialized processing capabilities are lost or are no longer in communication, local processing capability and storage can be used as a backup. If information has been automatically pushed into local storage, then it remains fresh. The same redundancy that buffers an organization from single-point failure can also buffer that organization from the time delays associated with the demand cascade that occurs in a memoryless system.

Arming and Annunciating Alarms

The clock-push CCIS is only partially adequate for alarm mode. Once a significant event is detected, an alarm is sent to the appropriate consumers. But the alarm may be impeded as it competes with scheduled information transfers for communications bandwidth. Alarm annunciation requires pure supply-push from detection through to the final consumer unimpeded by clock-push delays. The medium that moves data is and will continue to be unable to distinguish between information associated with the setting and annunciation of alarms and other types of information unless the alarm information is self-labeled. But that self-labeling is not always possible; hence the system needs to be able to expedite information when its status as an alarm becomes known.

Explicit alarms are set when a commander specifically states conditions that would violate his image or threaten his plan. Once an alarm has been identified, its detector can transmit the alarm annunciation as such and provide the alarm with preferential treatment throughout the information system. In many cases, insufficient attention is paid to identifying alarm conditions. Orders and intent should contain not just command information, but also control information. The staff needs to know how the commander will measure success and failure so that they can identify and even anticipate situations that threaten the plan. Plans, in turn, need to make these control measures explicit and must be back-briefed as well. Control measures should be sent to processors and collectors so that they can reconfigure their resources to monitor the success or applicability of a plan.

Explicit alarm setting may be treated in the same manner as a tree-mode demand as it travels throughout the system. Once it is received by those capable of detecting the alarm, however, its treatment must differ from that of a demand for information. Rather than providing an answer, the detectors of that alarm must maintain constant vigilance. If the alarm event never occurs, then the alarm demand will have no response and must be removed from the set of conditions requiring constant vigilance. If the event does occur, its annunciation must be supply-pushed with priority.

While recognition of alarms can in general be facilitated by the sharing of images among a command-post staff, this cannot be the case for alarms arising from higher-echelon intelligence information. Alarm setting is not distinguished from more standard information requests on standardized intelligence request forms, so the intelligence cells do not benefit from sharing in the commander's image. Until they are, they are precluded from detecting alarms, and alarms are prevented from receiving the preferential treatment they require.

Too often, an alarm is treated as a tree-mode demand or as another piece of information to be clocked back up the pipeline to consumers. The current communications system has mechanisms for transmitting information by priority. If an alarm is to benefit from higher-priority access to communications bandwidth than regularly scheduled information transfers, however, it must first be recognized as alarm annunciation. Alarm annunciation will follow the same path as clock-push information but must not be impeded by clocking (e.g., by scheduled communications and communications center personnel assuming that the intended recipient knows to come pick up the message). Alarm annunciation must be recognized as such if clocking is to be prevented.

Filtering the Pipeline

The clock-push nature of the current CCIS reflects the importance of scheduled decisionmaking and of the information flow that feeds it. It should be left as is. Moreover, storage changes by and large will not affect pipelines. In our efforts to improve pipeline functioning, we introduce the notion of *filtering* to protect the commander from information overload.

Regularly scheduled analytic tasks and briefings constitute an important segment of the command post's activities. Whatever information system is proposed must take into account the

importance of these tasks and the pipeline mode of information exchange that support them. The command post has a steady, predictable diet of information flowing through the pipeline that meets the needs of a great many command-post activities. The danger is that too much information or the wrong information will be pushed toward the commander and his staff, thus impeding their ability to find and focus on the information they need. This danger is averted by an information-*filtering* function, which typically constitutes one of the major tasks of the Chief of Staff.[7]

Filtering is the ordering, emphasizing or deemphasizing, including or excluding, and smoothing of information. Unlike analysis or synthesis, filtering typically produces information of the same level of aggregation as that of the consumed information. The Chief of Staff is able to filter because he shares the commander's image; that image can be viewed as subsuming implicit demands that identify the subset of pipeline information needed for the upcoming decision.

[7]Drenick (1986).

V. RECOMMENDATIONS: FULFILLING COMMANDERS' INFORMATION NEEDS

The previous three sections presented a way of thinking about commanders' information needs. The content of a commander's information needs is dictated by the situation, predominantly by the image the commander has of the battlefield. In order to provide the commander the information he needs, the staff must share that image. Accordingly, the flow of information both within and among command posts must be interactive.

Communication between commander and staff takes place in one of three modes: pipeline, alarm, and tree; the mode of information the commander requires rests on whether his image of the battlefield is intact or requires repair or reconstruction. In this concluding section, we discuss recommendations for improving the communication and understanding of images. Our recommendations pertain to the areas of *Army education and training* and *information systems design*.

EDUCATION AND TRAINING

General staff officers must be educated in the art of constructing, understanding, and communicating images as well as in the formal procedures of performing defined staff activities. Correspondingly, the training of EAB units at CPXs must be oriented toward the sharing of images between commander and staff. In this subsection, we discuss how both classroom education and unit training can be oriented toward the achievement of these objectives.

Institutionalize Back-Briefing

The commander not only must receive and disseminate information but must also be confident that he and his staff share the same image. This requires feedback: a round-trip ticket for the commander's image. We found this feedback to be present in well-functioning command posts but largely short-circuited in command posts that were under stress; ironically, this short circuit exacerbated the stress. We therefore recommend that procedures for ensuring

interactive information flow, particularly feedback of the commander's image, be institutionalized.

One means of institutionalizing these procedures is to firm up the role of the back-briefing. Although this concept is commonly understood, it is currently optional and is not taught as part of standard staff procedures. FM 101-5[1] lists four types of briefings: information, decision, mission, and staff; back-briefing is neither listed as a separate type of briefing nor discussed as an element of any of the listed types. We recommend that back-briefing be discussed in new versions of FM 101-5 and that it become part of standard mission briefings.

The old-fashioned way of assessing understanding is embodied in the commander's question to his subordinate, "Do you understand me, Colonel?" The invariant response to that question is "Yessir!" The back-briefing provides better insurance that the commander is understood, but unlike some insurance it is mandatory, not optional. Commanders should understand that omission of the back-briefing is gambling on understanding.

Teach Process as Well as Procedures

A general commanding an EAB unit is recognized, by the very nature of his rank and job, as an expert in military art. Our observations of CPXs led us to conclude that military expertise in the command post is in many ways analogous to expertise in complex decisionmaking arenas within the civilian world. Studies of civilian expertise suggest that experts do not solve problems the way we once thought they did. Previous views suggested that experts solve problems by the application of general principles and deductive steps that provide causal links between stages in a problem-solving sequence; in fact, this mode of problem solving appears to be quite rare.[2] To the contrary, the behavior of experts seems more intuitive than scientific; yet the evidence indicates that this intuitive behavior, *when exercised by an expert with a deep understanding and rich knowledge of his field and with information available to him on request*, produces effective decisions.[3] Experts in most fields tend to

[1]U.S. Army (1972), Appendix 1. The new version of this field manual about to be released, while making many substantive improvements, does not introduce back-briefing as a formal term.

[2]See, e.g., Schon (1983); Johnson (1984); and Kuipers, Moskowitz, and Kassirer (1988).

[3]Agor (1986).

solve problems and to make decisions by recognizing existing situations as instances of things with which they are familiar on the basis of their past experience. Thus, they know what data to examine and what steps to take to achieve a goal. They behave efficiently and proficiently, giving the impression of being smooth and effortless.

Experts are often unable to articulate the content and process of their expertise; much of their knowledge is tacit and their actions automatic, even to themselves.[4] Only when the situation is unfamiliar does the expert respond generatively on the basis of more fundamental principles. Even when under stress, experts, like other people, tend to fall back on their most automatic or familiar responses.[5] These characteristics make expertise difficult to study and, consequently, to teach.

Put into the framework of our study, generals (and other experts) think in images. Therefore, if the Army is to develop high-quality leaders and effective general staff officers, it must teach how to think in images. This is best accomplished through the provision of classroom opportunities to practice the processes used by experts as well as the procedures set forth in staff manuals. That is to say, in addition to *learning how to perform procedures correctly* (e.g., how to prepare a command estimate, with specifications about what information goes into which paragraph), officers must *practice the thinking process that the procedure expresses* (e.g., making actual, meaningful command estimates).

The trend of Army education has been toward more process teaching.[6] Small-group instruction (SGI), for example, is being adopted within the Army; during the 1986–1987 academic year, the CGSC significantly increased the use of SGI in the Command and General Staff Officers' Course (CGSOC) curriculum. This method of interactive education in a small-group setting (one instructor for 12 to 16 students) is used in 72 percent of the CGSOC required courses and in most electives, as well as in CAS^3 and School of Advanced Military Studies (SAMS) classes.[7] The basic difference between SGI and lecture-centered education lies in the fact that students acquire factual information outside the classroom largely on their own, thereby freeing classroom time for discussions and applications. The

[4]Goleman (1987).

[5]Zajonc (1965).

[6]Wass de Czege (1983) recommended a number of changes to CGSC in this regard, including the establishment of the School of Advanced Military Studies. Our analysis entirely supports his; our recommendations here take his a step further.

[7]Pearlman (1987).

main purpose of the classroom thus becomes the honing of judgment and problem-solving skills.

Despite the advent of SGI, current CGSOC education still dwells too much on procedural matters, discussions of historical examples, and philosophical concepts, and not enough on the development of expertise by doing. In this report, we suggest several ways in which these skills could be better developed within the framework of SGI. The common theme in all of these methods is the opportunity for repeated exercises of processes so that students, with practice, automatically use the skills of the military artist.

Teach Explicit Ways of Assessing Understanding. Successful command and control depends on accurate communication. In each phase of the process of translating images to action, commanders and their staffs must depend on the fact that they understand each other. As in everyday conversation, understanding is assumed until someone asks a question or otherwise indicates some misunderstanding. When misunderstanding occurs, people naturally seek clarification. In wartime, however, understanding may be a dangerous assumption. Just as commanders learn to monitor the outcome of their orders on the battlefield, so must they learn explicit ways to assess understanding rather than taking it for granted.

One way to exercise "understanding" would be to present guidance and statements of commander's intent that were purposely ambiguous. Discussion could then center on the possible interpretations of that intent, on whether different interpretations would in fact lead to different actions, and on the reasons different perceptions arose. During one CPX that we observed, a corps commander asked the division commander whether his intent had been clearly stated. A lengthy, largely staged conversation ensued that raised a number of questions regarding intent: Where does it go in the order? Should it be published, or must it be orally communicated? How can it be clarified if face-to-face contact is not possible? When might misunderstandings of intent occur?

This conversation, although perhaps misplaced in the middle of an exercise, was precisely the kind of discussion that should take place in a classroom. Students could then decide which interpretation was meant and could practice rewriting the guidance or intent more clearly.

Another way to teach understanding would be to take literally one division commander's observation that intent is understood as long as it can be translated into a task. The class would be given the ambiguous guidance and intent and would then be divided into small

groups. Each group member would subsequently assume a particular staff role, such as the G2 or G3, and would then develop and discuss particular courses of action. This activity would cause students to deal with ambiguities as they attempted to turn intentions into plausible actions; the differences among groups would illuminate the dangers of ambiguity.

Stress "Flexibility" of Information-Processing Behaviors. Historically, Army education was teacher-centered and focused on teaching approved school solutions. Written lectures were screened in advance to ensure that nothing contravened doctrine; unorthodox points of view were neither entertained nor analyzed.[8] Although SGI counters this trend, there must be even more opportunity to challenge hierarchical patterns of authority common to the classroom and the Army. Students need to be encouraged, and even rewarded, for suggesting unconventional approaches and solutions that can be discussed, analyzed, and argued.

An analogy that could be exploited here is the "creativity" test. Standard tests of creativity require that one take a problem and produce a creative solution, which is scored to some criteria. The challenge here would be to produce solutions that were also defensible.[9] Students could either brainstorm and defend alternatives as a group or form small teams that competed for the most unusual, yet feasible, solution. The class as a whole could then establish the criteria for scoring creativity.

Another way to train for flexibility is to educate students about pipelines, alarms, and trees. Each of these modes is important for satisfying a commander's information needs, and each places particular demands on staff members. Students should be trained to analyze a situation to determine what the commander's image was and whether or not that image was understood. The state of understanding in the command post would dictate what the appropriate communication mode would be. Students in a classroom exercise might take a descriptive scenario, such as the "Five O'Clock Follies" that introduced Sec. III, and identify different modes in it. They would then consider what a particular staff member would be required to do to obtain information in various circumstances or how the Chief of Staff could effectively perform his "information-filtering" role. The scenario might introduce barriers to finding information

[8]Ibid.

[9]Torrance (1986) reviews recent work on instructional techniques to foster creative learning.

(e.g., a regular communication channel is inoperative or the computer system is down) to encourage students to think about alternative information channels.

The goal of such an exercise would be to use the concept of information modes to help students understand the inherent flexibility of information processing. While modes are useful descriptive tools for thinking about command-post communications, we do *not* recommend that they be made part of established procedures (e.g., a list of times to enter tree mode).

Use Case Studies to Develop Experience. Currently, commanders and their staffs gain experience in the art of constructing, understanding, and communicating images through various types of training exercises. These exercises typically simulate warfare, often driven by computer-based models, with an eye toward providing opportunities to practice decisionmaking and formal staff procedures. These models have a number of limitations that make them imperfect training drivers; for example, they are expensive to run and do not capture many of the nuances of personality, happenstance, and unexploited opportunity that drive much of real decisionmaking. An alternative model, and one that can be used in the classroom, is the "case study" approach.

The case study approach is often used in business schools to teach decisionmaking. The basic principle is to present students with information about a real company or organizational unit, to pose a problem that requires a decision, and then to ask, "What would you do?" Students work through the problem and defend their solutions or actions to the class. Students are given a wide variety of cases and thereby gain exposure to different decisionmaking situations.

We suggest that case studies be developed from historical examples. A carefully documented case of actual corps or division operations in wartime could, for example, convey a great deal of information about the principles of AirLand Battle in a real case and point out the doctrine's inevitable vagueness when applied to reality. The case could be tailored to develop several decision points in one campaign, each addressing specific division-level problems—logistics, control of civilians, fire support, maneuver, and so on. Problems could be presented that might be solved differently by different specialties; for example, a problem of low supplies would be handled differently by logistics, maneuver, or transportation staffs. Since cases would be based on history, some aspects of warfighting are likely to have changed. Thus, a key part of any case would lie in isolating what is different about today's situation and asking how

such differences would change the options a commander considered. Students could work on the case as a group by trying to solve it from a particular staff member's perspective or by taking multiple perspectives. A series of cases in the curriculum would also serve as common reference points that all officers would recognize in similar terms—e.g., the "Okinawa" case or the "Bien Hua" case—and use to convey complex ideas in shorthand.

The difference between the case approach and history courses can be found in the structuring of the historical case to present particular issues or problems toward a decision point. A key to making this approach work is to train instructors as facilitators who can make the case come alive in the classroom and force students to think about their options.

See the Image from a Different Perspective. The team of the commander and his staff is composed of specialists who come together to produce, in effect, a consensus product—i.e., the image of the battlefield. Each individual views the image from his individual lens, which is somewhat specialized with regard to education, training, and experience. Each brings a specialist's expertise to a complicated problem-solving situation; the knowledge required to produce a successful outcome is distributed among them. Differences in background and the tasks required of each team member necessarily produce differences in the image of the battlefield. A final skill that is useful for image building, particularly for resolving misunderstandings about the image is the ability to view the image from a different perspective.

Role playing provides one means of broadening perspective that is well suited to a classroom exercise.[10] This exercise requires that students be assigned to act outside their area of specialization; for example, an intelligence officer would play the G3, a logistics officer the G2, and so on. Currently, intelligence officers across echelons share images about what a certain maneuver by the opposing force might imply for their overall plan of action or about the strengths and weaknesses of a particular Intelligence Preparation of the Battlefield (IPB). These same officers, by virtue of attending CAS^3 and CGSC courses with operations and logistics officers, should gain an appreciation of the role of intelligence in the combined arms arena that characterizes EAB; unfortunately, this ideal case has yet to be realized in the actual world.

[10]This technique has been used successfully in reciprocal teaching and other instructional methods (e.g., Collins et al., 1987).

Such role reversal, which can be exercised vertically as well as horizontally, provides students with better perspectives on how others will comprehend and act on the products of their own work. This role playing could easily be accommodated in the exercises sketched above. In addition, the instructor should focus discussion on what each individual learned about the role he played and what effect that understanding might have on the way he does his regular job.

The conditions of the decision exercise (or case study) could be shaped to focus on a set of roles that are important in that context. An exercise on rear battle, for example, could emphasize logistics and combat support service elements. In role-playing exercises, students should not be expected to perform well in their new roles but should be expected to learn image-sharing and image-confirming techniques. In this way, they will gain insight into the constraints or advantages that others face in relation to their accomplishment of the mission.

Train Unit Command Staffs to Share Images

In wartime, commanders and staffs form cohesive teams. For example, Generals MacArthur and Patton kept their general staffs virtually intact through a number of commands during World War II. In peacetime, the realities of rotation and promotion policies create substantial turbulence at the command post. Thus, the sharing of images that arises from teamwork is not automatically present in a peacetime Army; instead, it must be consciously maintained.

The Army's principal means of training EAB in peacetime is the CPX. In particular, the Army has an extensive and growing investment in computer-driven CPXs. Such CPXs use models that "run the war," implementing higher-echelon operational art and tactical plans over several days to several weeks of a major operation. While there is general agreement that these computer-driven CPXs are of great potential value, there is an equivalent consensus that their potential is far from realized.

A critical gap between the potential and the reality of computer-driven CPXs lies in the extent to which they can instill team functioning in the unit. This purpose is regarded as an important component of higher-echelon training;[11] in our terms, it means

[11]Team building is one of the major purposes of the Battle Seminar phase of the newly instituted Battle Command Training Program (BCTP) at Fort Leavenworth. The Battle Seminar combines computer-driven decision exercises and doctrinal workshops to prepare divisions and corps for a major computer-driven WarFighter Exercise CPX.

learning how the commander thinks in order that the staff can help build and share with the commander a common image of the battlefield.

Our observations lead us to conclude that current CPXs teach of procedures but are not effective in teaching an understanding of the commander's intent in different situations. What is lacking are opportunities for the commander and staff to "read" each other and to practice turning intent into action over a range of circumstances. We recommend that this gap be filled through the development of "sketchbook decision exercises." A sketchbook is a planned sequence of small computer-supported CPXs focused on specific thought problems over a wide range of situations. As such, it represents an elaboration of the classroom "mapboard exercise" or "vignette" common in Army training. Sketchbook exercises would precede, not replace, full-blown CPXs.

Sketchbook exercises offer clear advantages for image sharing. By providing multiple, varied opportunities for commander and subordinates to "read" each other, the sketchbook gives command-post staff an opportunity to learn the idiosyncrasies of the commander's image. When exercises cover the same situation again and again (as is the case in the standard TRADOC European [U.S. Army Training and Doctrine Command] teaching scenario), the staff learns only how the commander thinks about that single situation; there may be characteristics of that situation that would not be duplicated elsewhere. By studying a variety of situations, the staff sees the commander displaying a variety of images and can learn by inference the major dimensions by which the commander characterizes situations.[12]

Furthermore, a standard scenario might not exercise the warfighting skills that specific units need in likely combat situations. For example, light and motorized divisions that specialize in mobility probably do not get an opportunity to train optimally when their exercise experiences consist primarily of missions that are more likely to be given to armored divisions.

Sketchbooks also give the staff an opportunity to obtain information in the context of the commander's image. They do so by allowing the staff to prepare many different types of information in

[12]We anticipate a justification of repeated plays of the same scenario by claiming that computerized data bases exist only for these scenarios. This justification strikes us as being in the same league as the justification given by the inebriate for looking for his lost keys under the lamppost: he hadn't lost the keys there, but it was the only place where there was light enough to look for them.

response to varied situations and, through feedback, to learn the commander's needs in these different contexts.

Sketchbooks also provide valuable practice for turning images into actions. Repeated plays of the same situation become exercises in procedures; we have seen CPXs where staff members spend most of their time thumbing through manuals to find the right wording for standard paragraphs. Instead, the novelty of each sketch forces the staff to think about the image and about how this unique concept of operations needs to be converted into a set of orders and guidance.

Once a unit has experienced the sketchbook of exercises, then a full-blown CPX, focused on one of the major missions of the unit, can test in full the implementation of procedures and processes. In this way, both the structured and spontaneous thinking of the commander and staff can be practiced and perfected.

INFORMATION SYSTEM DESIGN

Our recommendations for information system design are cast in the context of the existing CCIS network. The current CCIS is an extremely large complex of human and electronic components that will not be revolutionized by anyone's recommendations. It relies instead on a communications infrastructure of existing radio and telephonic equipment that will evolve slowly even as there are revolutionary changes in technology.

The common driver to our recommendations is the need for the CCIS to support image sharing. Our recommendations fall into two categories. The first is aimed at elevating the level of message traffic and message medium to more naturally support image sharing. The second is directed toward providing a conceptual framework for information system designers to ensure that the CCIS supports all three information exchange modes, because each mode plays an important role in image sharing.

Identify Means of More Direct Image Sharing

The first category of recommendations is based on the recognition that images exist in the heads of the commander, his staff, and his subordinates and that messages passed back and forth between them serve to challenge, maintain, and alter those images. The detailed information that is passed in the message traffic sometimes obscures the image-sharing process. The Army should therefore seek to "build sidewalks where people walk"—that is, to exploit and improve those

means of image sharing that already work and to ensure that information systems, whether human or automated, support these means. Some of these means, such as the Army's common understanding of military history, are already highly developed, while others—for example, dynamic maps—are not.

Exploit the Army's Rich, Common Understanding of Military History. Staff officers and commanders share a rich, common understanding of military history. This is inevitable given that they study the same battles and commanders from the same sources. One need only mention "Patton's turn to the north" to evoke a highly complex image that most military professionals understand. This type of verbal understanding, while common in oral communications, is less apparent in paper or electronic communications. Moreover, because of the "informal" nature of such image invocation, they are sometimes believed inappropriate in formal settings such as decision briefings. Our recommendation, to the contrary, is that such direct image invocation be encouraged in formal as well as informal settings. We also recommend that officers in Army educational settings be reminded of the communication value of the military history that they are studying.

Exploit the Media Qualities of Maps. The number of hours commanders and staff spend in front of maps during planning sessions and decision briefings gives strong testimony to the value of the map as a communications medium. The conversations going on in front of maps invariably involve staff officers trying to describe a very dynamic battlefield with an oral description of an event sequence; there is always a series of hand movements over the static map. By contrast, the time-lapsed weather map on the evening news uses a dynamic display to describe a dynamic process with much greater success, with far fewer words, and with much less confusion. We don't suggest doing away with the very valuable pointing and hand waving; instead we recommend that ways be found to improve the map as a communications medium and to transmit some of the understanding gained by pointing and hand waving to people who are not present at the time.[13]

Dynamic map displays are not unknown to Army training; the National Training Center (NTC) at Fort Irwin, California, makes excellent use of such displays in its After Action Reviews. The

[13]Our recommendation here is restricted to improvements within any given command post. While the benefits of an interactive map display technology that linked command posts would be tremendous, such a technology is beyond our present capacity.

transfer of technology from the television weather map or from the battalion-level resolution of the NTC to that required by EAB is neither inexpensive nor easy to develop, but it is an objective that is worth achieving.

Build a Hybrid Information System

In Sec. IV, we attempted to inform the demand-pull/supply-push debate and to offer a hybrid of information flow and information storage techniques as an alternative. The hybrid was motivated by the need to support the three modes of information exchange. Here, we suggest concrete ways to implement such a hybrid system.

Retain the Supply-Push Orientation to Support the Pipeline Mode of Information Exchange. Replacing the supply-push orientation in favor of demand-pull may improve support for tree mode and may avert information overflow, but it would create a problem in the system where none currently exists. Regularly scheduled information flow that is currently pushed without request will have to be demanded, thus consuming communications bandwidth and requiring increased coordination without providing commensurate benefit. Our observation is that there is a great deal of regularly gathered, processed, and transmitted information that should continue to be handled in the manner it is today—pushed through the pipeline on schedule.

Add Local Storage to Support Tree Mode. Although demand-pull seems to be the more natural paradigm for the support of tree-mode information exchange, we recommend that the current supply-push orientation be continued and that it be pushed into a short-term local storage facility from which the Chief of Staff could filter. A supply-push to the command-post storage facility and a demand-pull from it by the Chief of Staff would create an orientation that would not just consider flow through the system but also view the system as a distributed information base. Commander's tree-mode demands (demand-pull) could quickly be met by access to local storage and would not suffer the excessive delays inherent in relaying the demand back to the original producer. The potential for demand cascades and the associated time delays make demand-pull undesirable for the support of tree mode.

Add Local Processing Capacity to Support Tree Mode. Local storage alone is not in itself a solution. Owing to the highly varied level of aggregation of commanders' requests in tree mode, local storage must either subsume all levels of aggregated information or

contain relatively raw information accompanied by the capacity to quickly access and process it into the finished information requested. This implies that local analytic capability be collocated with the information and the commander. It need not be as sophisticated as specialized processing cells located outside the command post. Previous studies of command information (see the appendix) can serve as a basis for the partitioning of the distributed information base.

Increase the Chief of Staff's Ability to Filter Information. We have observed that many Chiefs of Staff frequently circulate between the commander and the assistant chiefs of staff, acting as a filter of information being gathered and processed by the assistant chiefs destined for the commander. This behavior appears to be effective in buffering the commander from information overload. We recommend that this system be encouraged and that this portion of the CCIS be augmented to increase the Chief's ability to be an effective filter.

Use the Storage Dimension to Buffer Against Time Delay and Hostilities. In the hostile environment in which collecting, processing, and communications resources exist, there is leverage to be gained by anticipating failure and providing redundancy. If information is remembered in more than one place, then the organization that relies on it can be more tolerant of single-point failures, assuming that redundant processing capability is also provided. The same redundancy that buffers an organization from the time delays associated with the demand cascade that occur in a pure-flow, storageless system can buffer an organization from disruption of collection, processing, and communications.

Add the Store-and-Forward Concept to Information Flow. Augmenting information flow with correctly placed local storage bridges gaps in the communication system while buffering the command post from communications delays and communications system failure. One symptom indicating overemphasis on flow can be found in messages and reports flowing out of a communications path onto hardcopy. If the information needs to be forwarded, it must be transcribed from hardcopy back into a form that is acceptable to the communications network. Information stored as hardcopy is not amenable to analysis or even to retrieval if the commander asks for it unexpectedly. Instead, communications should terminate in a database from which information can be forwarded, printed, retrieved, cross-referenced, or analyzed.

Establish an End-User to End-User Communications Orientation to Preserve Response Time for Tree and Alarm Modes. The high cost and high degree of specialization of personnel and equipment found in communications and intelligence centers introduce barriers between information producers and consumers. The high cost of these centers demands that their services be shared by many users. It also means that their understanding of any specific user is undesirably limited. This limitation is not overwhelming if centers are operating in a clock-push or supply-push environment, i.e., if they are supporting pipeline information exchange. It can, however, have serious effects when it supports alarm- or tree-mode information exchanges.

Communications centers exist in their current fashion because their expense dictates that they be an asset shared by everyone in the command post. The situation is not unlike the days before wide dissemination of the telephone, when the telegraph served as the primary means of rapid long-distance communication. At that time, one went to the telegraph office, where a skilled person using exotic equipment tapped out a message to another telegrapher in a neighboring town. After some unpredictable time delays, a response returned. The telegrapher, who monitored all of the message traffic, was responsible for identifying the response and delivering it to the requestor, who may have been anxiously waiting at the telegraph office for hours, may have dropped in every hour or so hoping to find his response, or may have gone about his business expecting a small boy employed by the telegrapher to track him down with the message. In most of the developed world, the telegraph system has been replaced by a telephone system with a direct end-user to end-user orientation.

Communications Centers Must Accept Responsibility for Getting Messages to the Recipient in a Time Commensurate with the Needs of the Information Being Exchanged. Current communications centers still retain some of the flavor of the old telegraph office. They are active with respect to the communications network that they feel responsible for but are far more passive when it comes to the recipients of incoming messages. They will dutifully log an incoming message as soon as it arrives, move the message to the recipient's mailbox, and consider their job done. This is fine if the message is being pushed through the pipeline on schedule and if the recipient knows when the message will arrive and can be there to meet it. Messages that contain alarms will arrive, will be logged in, and will languish in the recipient's mailbox. Communications centers

must not presume that recipients know when to come to the communications center but must instead directly connect end users of the communications system.

The alarm mode of information exchange imposes additional challenges for the designer of the command-and-control information system. The alarm must be set, detected, and annunciated. Commanders must convey not only their image of the battle, but also what constitutes a violation of that image. It is not possible to make explicit all violations; hence the only solution is one that is derived from shared understanding (implicitly setting alarms).

Alarm-Setting and Tree-Mode Requests Must Be Distinguished to Expedite Alarm Annunciation. Some alarms can be set explicitly—as would occur, for example, when the commander tells his intelligence officer that his current plan assumes that a particular enemy unit will not move in the next 24 hours. But the intelligence officer must rely either on his unit's organic intelligence assets to detect movement or on assets belonging to higher echelons. If the alarm must be detected outside the concerned command, the current system implements the alarm as a tree-mode inquiry. For example, the location of a particular enemy unit may be requested repeatedly from a higher-echelon intelligence shop to determine if the unit is moving. Specialized intelligence cells may not be in a position to share the image of the commanders they are supporting. As with tree mode, the response to the inquiry containing the alarm may arrive, may be logged in, and, far too often, may be placed in the recipient's mailbox with the expectation that the recipient will come check if he is expecting an important piece of information. The sender of the alarm does not know that he is sending an alarm, and the communications center does not know that it has received an alarm. Only the recipient will know, and only after he ventures to the communications center. Again, the end-to-end orientation will help, but the real solution is for the commander to be able to communicate his image to the remote intelligence collectors. This allows them to detect an alarm rather than merely to answer a question.

Information Requests Should Be Accompanied by a Self-Addressed, Stamped Envelope. Like a communications center, the expense and high degree of specialization of a higher-echelon intelligence cell requires that intelligence requests come from a wide audience of consumers. When requests are batched together and a mission planned—e.g., in an aerial reconnaissance—the identity of all requestors may be batched together into a subscriber list. When the

mission is complete, the intelligence analysts may broadcast the entire mission results to its subscriber list in a supply-push manner. The right information may be in the mission results somewhere, but it remains for the requester to find it. Vital information may become lost in a mass of data. The solution is to design information collection and dissemination systems that maintain the coherence of the information requests such that responses can be selectively sent to requestors. Put another way, information requests should be accompanied by a self-addressed, stamped envelope.

Appendix

ENUMERATING COMMANDERS' INFORMATION NEEDS: A LITERATURE REVIEW

Command and control is one of the most extensively discussed and written about military topics; a literature review of the whole of that field would be impossible and, in any case, of little benefit. Here, we present instead a detailed review of five recent efforts to determine EAB commanders' information needs.[1]

CORPS INFORMATION FLOW

The first study[2] attempted to examine the flow of information to corps command posts. It was conducted in three phases. The first phase focused on the minimum information needs of corps commanders, the second on corps-level staff officers, and the third on commanders at echelons other than corps. The study employed a top-down analysis aimed at determining the minimum information that the corps commander needs both to manage the corps combat effort and to trace the flow of information to the commander from its sources.

A sample of general officers used a modified Delphi methodology to analyze the 11 TRADOC-defined[3] functional battlefield systems, to determine the information required by each system, and to assess subjectively what use could be made of that information. If the information did not assist the command in fighting the current battle or in planning future battles, it was rejected. Rejection meant simply that the commander did not require it on a continuing basis.[4]

Thirty-eight basic information needs were identified. These were supplemented by needs required to meet special situations or to satisfy particular requirements of individual commanders. Paths of information flow from various sources, through prescribed buffers, to

[1]See U.S. Army CACDA (1985b) for a chronology of other efforts to identify critical information requirements for force commanders.

[2]U.S. Army CACDA (1979).

[3]TRADOC is the U.S. Army Training and Doctrine Command.

[4]Rejection was specific to a phase of the study. Thus, information rejected by the corps commander might be deemed necessary by corps staff.

the corps commander were identified. The flow analysis refined each of the 38 needs into information elements and sources and then identified the communications currently available to support the flow. Direct communications between commanders, although recognized as instrumental in providing essential information, were not identified in the information flow so that commanders would not be bound to a particular reporting system. Standard operating procedures (SOPs), including timeliness requirements, responsibilities for information formulation, and prescribed specific reports, were established. Finally, the analysis specified example graphics, consisting of either situational maps or alphanumeric matrices, for each of the 38 information needs.

ESSENTIAL ELEMENTS OF INFORMATION STUDY

The second study[5] attempted to identify the essential elements of information (EEIs) for a prototypical U.S. Army corps commander engaged in a nonnuclear land war in a European theater multiple-corps front. Beginning with a generic statement of the mission and the command level chosen, a set of minimum essential functional tasks (MEFTs) was developed to describe the procedures at the command level. Each MEFT was logically subdivided into more definitive subtasks until the tasks were single specifiable actions. For example, a MEFT of "establish disposition of enemy forces" would ultimately be reduced to "determine location of enemy Unit X." EEIs were then defined as those individual items of information needed to carry out the MEFT. The number of EEIs needed for a single MEFT, multiplied by the total number of tasks, provided the total number of EEIs required.

This study explicitly avoided a consideration of existing and notional automated technologies in the belief that concentration on technology would hamper rather than aid in the identification of key information needs. The "factor decomposition" approach was not scenario oriented, since the investigators believed it impossible to conceive of all possible scenarios within a broad mission.

Five MEFTs were factored: (1) see the battlefield; (2) determine enemy intentions; (3) project the impact of the environment on the battlefield; (4) evaluate the progress of the battle; and (5) support the battle. These do not account for all the corps commander's essential tasks; for example, he also has responsibilities to respond to civilian

[5]Lockheed (1981).

needs. The analysis identified 570 different types of information elements required by the corps commander. A given EEI could occur a number of times, depending on the situation. The EEIs for roads, for example, occur as many times as there are roads on the battlefield. Thus, satisfaction of the 570 different types of information requires summing over occurrences; this analysis yielded 62,900 EEIs! To answer any question the corps commander might have about a battle in such a conflict would ideally require that all these EEIs be collected and updated. A breakdown of the 62,900 elements indicated that 47 percent were about battlefield topography or related information that could be found on maps. Of the remaining elements, 35 percent identified changes in force element status, dispositions, etc. The latter are more amenable to handling by automated information systems.

I CORPS INFORMATION QUALITY ANALYSIS

A 1985 study of information needs in the U.S. Army I Corps,[6] based on interviews with I Corps staff officers, identified 748 discrete information requirements (IRs) needed to execute combat duties. These 748 IRs were necessary to the accomplishment of 141 discrete tasks in the five major functional staff areas (personnel, intelligence, operations, logistics, and civil-military operations). Interviewees were asked to identify precisely the data they would need to perform their duties. Of the 748 IRs, 20 were deemed critical to the prevention of catastrophic failure in the implementation of the corps war plan. An additional 64 were cited as necessary.

The tasks and IRs were further rated according to "qualifiers" (e.g., automated, oral, mission crucial, and mission required) and problems of information supply (e.g., late/untimely, nonexistent, unusable). They were then "clustered" so that shared data elements could be identified. The clustering facilitated data base construction and information distribution in an automated system.

A principal study conclusion was that too many of the 748 IRs were untimely. This tardiness was attributable in part to the data being generated outside corps control. In addition, the study noted that information did not always get to those who needed it because some staff sections were unaware of all the users of the information they generated.

[6]U.S. Army CACDA (1985a).

The cluster analysis of the 141 corps tasks yielded a structure of tasks that followed traditional staff lines;[7] it also showed an additional "warfighting process" cluster that drove most of the subsystems in the decision cycle of corps operations. Other analyses determined that automation would have the greatest payoff in intelligence and operations processes.

COMMANDER'S CRITICAL INFORMATION REQUIREMENTS (CCIR)

The division CCIR study[8] identified the key information elements required for a division commander's decisionmaking process. Like the I Corps study, an objective of this study was to inform baseline requirements for automated command-and-control systems, decision graphics, and artificial intelligence. The approach was first to survey 28 active division and corps commanders and commandants of branch schools to determine if there was a consensus on a set of critical information requirements. A general officer working group was then convened to discuss and validate the list of requirements generated by the survey. Finally, independent evaluations further validated the product and identified potential oversights in CCIR specification.

The study isolated a number of information elements that were deemed critical to a division commander's decisionmaking process. These elements include raw data that are given to the commander as well as processed information requiring assessment by subordinate commanders or staff officers. Eight information categories, each with specific subelements, were identified: command guidance, maneuver, intelligence, fire support, air defense, battlefield geometry, combat support, and combat service support.[9] The CCIR information elements were compared with 83 information items listed in the Force Level Information Requirement Plan (FLIRP),[10] the data base definition document used for all objective automated command-and-control systems. The 24 CCIR items were a subset of the FLIRP items; 22 of these were selected by at least two-thirds of the

[7]This is hardly surprising given that the data came from officers working in those traditional staff lines.

[8]U.S. Army CACDA (1985b).

[9]The resemblance of this list to the seven major battlefield operating systems is undoubtedly not coincidental.

[10]The FLIRP was developed by the U.S. Army Combined Arms Center over a period of several years and was approved by TRADOC in February 1983. The CCIR effort is in part regarded as a refinement of the FLIRP.

respondents. These were considered essential mission information requirements.

A number of this study's conclusions addressed the command-post information system. Since the commander must have access to the CCIRs from any command-designated location on the battlefield, the command-and-control system must either distribute CCIRs to all locations or support a query capability from any location. Each CCIR must pass through either an automated or a manual (e.g., staff officer) "processor" prior to entry into the commander's data base; each processor should have the responsibility to update his own assigned CCIRs. CCIR information thus designated must take priority in information distribution throughout the command-and-control system. The CCIRs provide only baseline requirements; different information needs for different echelons or mission-specific CCIRs must be added to automated command-and-control systems.

A follow-on study[11] attempted to validate the CCIR by surveying 16 commanders and staff officers at corps, brigade, and battalion levels. This study, done by MITRE for CACDA, looked more closely at the demands that information might place on existing and proposed automated systems. Among its findings was that information in the five functional areas is compressed into a single commander-to-commander communication channel. It concluded that the need for automation is largely within the staff communication channel, where information can be exchanged rapidly and accurately to support the commander's intent. Not surprisingly, then, the number of information elements identified as critical by staff officers greatly exceeded those of the commanders.

THE ART AND REQUIREMENTS OF COMMAND (ARC) STUDY

A final study[12] we examined attempted to develop and test a methodology for studying the art and requirements of command, to document a composite portrait of the commander in the command process, and to develop a preliminary command-control support requirements model as a basis for future research. We present this study last, even though it is the oldest, because it differs in nature from the others and is the closest to our own orientation; regrettably, it appears to have had little impact on the Army. This study differs

[11]Herren and Moak (1986).
[12]Bloom and Farber (1967).

from the other studies in that it departs from the traditional systems or task-analytic approaches to take a behavioral view. Its focus throughout is on the commander and on his requirements for communicating and for receiving objective and subjective information:

> As long as the command-control function is exercised by commanders relying principally on other humans for support, training and individual experience need to be emphasized in doctrine and in the development of requisite command-control support systems.[13]

The methodology was developed from three lines of inquiry: questionnaires and interviews with general staff officers, a historical study, and a study of the Seventh Army command process. Data from these three sources were integrated and analyzed by an interdisciplinary team of operations analysts, social scientists, and experienced senior commanders. Follow-on phases of the study (not, to our knowledge, ever completed) were intended to verify the model through further data collection and to make recommendations for organization, doctrine, training, and hardware.

The ARC model viewed command as an information transfer process and specified, in very broad terms, the content and mechanisms for input and output for four stages in the command process: (1) mission evaluation and interpretation; (2) issuing of directives; (3) monitoring the development and the preparation and issuance of coordinated plans and orders; and (4) follow-up and evaluation during operations. For example, the model for the third stage includes the following components:

- *Input content:* a directive understood and accepted by staff and subordinate commanders.
- *Input mechanism:* direct monitoring by the Chief of Staff and indirect monitoring by the commander (in the form of spot checks, visits, briefings, etc.).
- *Output content:* plans and orders for operations in the hands of subordinate commanders.
- *Output mechanism:* personal visits, telephone and radio communication, issuance of written orders, etc.

In the descriptive framework of the study, the commander is at the center of this process as he receives the inputs of information to the

[13]Ibid., p. vii.

command post and supplies or directs the outputs (in the form of, for instance, orders, requests for more information, or questions to subordinate commanders).

The ARC study concluded that the commander's basic problem lies in the effective acquisition and dissemination of information. But the elaboration of that conclusion was not in the direction taken by the other studies. Face-to-face personal contact between the commander and his staff and between subordinate commanders was seen as an essential part of the command process. These personal visits cannot be supplanted by technological devices; *both* technology and personal contact are essential to the successful exercise of command. The commander's information demands and requirements are so great that technology and personal contacts combined cannot totally satisfy them; partial substitutes or human filtering mechanisms are necessary.

By viewing the process of command and control as an information transfer process, the study postulated critical factors and then tried to determine where partial, and perhaps technology-based, substitutes might be introduced. For example, voice communication, as opposed to written communication, enables commanders to know their staffs better; new technologies that improve or enhance voice or face-to-face communications are therefore to be preferred to improvements in written communication.

The ARC study suggests the following critical elements of command information:

- Personal contact is essential;
- Commanders require both objective and subjective information;
- Information must flow both to and from the commander;
- Mechanical communications and information systems can supplement but not replace human mechanisms for gathering and disseminating information;
- The type and level of detail of information required vary; and
- The organization of required information varies primarily with the commander and with the situation.

The impact of some of these factors on command and control is briefly sketched in the study. For example, the commander needs humans to filter much of the information coming his way, but there is

no guarantee that the commander's and the filter's perceptions agree. This "psychological" distance necessarily introduces error into the process.

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